ANL/ESD-18/5

Non-Light-Duty Energy and Greenhouse Gas Emissions Accounting Tool (NEAT): Documentation and User Guide for Updated Domestic Freight Component

Energy Systems Division

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Non-Light-Duty Energy and Greenhouse Gas Emissions Accounting Tool (NEAT): Documentation and User Guide for Updated Domestic Freight Component

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NOTATION

The following is a list of acronyms and abbreviations used in this document. Some acronyms used only in tables may be defined only in those tables.

GENERAL ACRONYMS, INITIALISMS, AND ABBREVIATIONS

AEO	Annual Energy Outlook
Btu	British thermal unit
CFS	Commodity Flow Survey
DOE	U.S. Department of Energy
Dom	domestic
DOT	U.S. Department of Transportation
EIA	Energy Information Administration
FAF	Freight Analysis Framework
F-T	Fischer-Tropsch
GHG	greenhouse gas
GREET	Greenhouse Gas, Regulated Emissions, and Energy Use in Transportation
hp	horsepower
ICE	internal combustion engine
LNG	liquefied natural gas
MPG	miles per gallon
MWh	megawatt hours
n.e.c.	not elsewhere classified
NEAT	Non-Light-Duty Energy and Greenhouse Gas Emissions Accounting Tool
SCTG	Standard Classification of Transported Goods
TEDB	Transportation Energy Data Book
VIUS	Vehicle Inventory and Use Survey
VMT	vehicle miles of travel

NON-LIGHT-DUTY ENERGY AND GREENHOUSE GAS EMISSIONS ACCOUNTING TOOL (NEAT): DOCUMENTATION AND USER GUIDE FOR UPDATED DOMESTIC FREIGHT COMPONENT

1 INTRODUCTION

The Non-Light-Duty Energy and Greenhouse Gas Emissions Accounting Tool (NEAT) was developed to help evaluate various scenarios of non-light-duty transportation demand, mode choice, energy intensity changes, and alternative fuel use. The model was initiated as a part of the Transportation Energy Futures Study conducted jointly by the National Renewable Energy Laboratory and Argonne National Laboratory. The development work was funded by the Department of Energy's Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Office.

NEAT uses existing base case projections of freight ton-miles by commodity (type of goods moved), associated mode shares (percent of ton-miles moved by various modes), and modal energy intensity by commodity (energy consumed per ton-mile of a given commodity when moved by a given mode). The model also contains base case shares of fuels consumed by five freight modes (percentages of various fuels consumed by a mode):

- intercity heavy trucks
- freight rail
- domestic marine
- air freight
- pipeline

The fuels used by these modes are:

- petroleum diesel
- biodiesel
- Fischer-Tropsch diesel
- pyrolysis diesel
- liquefied natural gas
- petroleum jet fuel
- hydroprocessed renewable/Fischer-Tropsch jet fuel
- pyrolysis jet fuel
- residual fuel oil
- natural gas
- electricity

This document describes the procedures used for developing the base case data for the 2017 version of NEAT. It also provides information on how to use the updated NEAT.

For each mode and fuel combination, NEAT uses greenhouse gas (GHG) emissions and upstream energy use rates from the latest version of Argonne's GREET (Greenhouse Gas, Regulated Emissions, and Energy use in Transportation) model (Argonne 2013). NEAT attempts to match mode-level historical energy consumption values from Oak Ridge National Laboratory's *Transportation Energy Data Book* (TEDB; Davis et al. 2012, 2016). Future energy intensity improvements are estimated from Annual Energy Outlook projections made by the U.S. Department of Energy, Energy Information Administration (EIA 2017). Because both of these sources use higher heating values for fuels, GREET's lower-heating-value-based emissions rates are modified to reflect our use of higher heating values.

NEAT is designed to allow the user to evaluate alternative scenarios related to non-light-duty modes. However, the current version covers only the domestic freight modes. International marine and commercial aviation will be added in the future.

NEAT uses commodity-level ton-miles, mode shares, and modal energy intensities to estimate end-use energy consumption through 2050. It uses fuel shares by mode to allocate fuel consumption to various fuels used by each mode. The tool then estimates GHG emissions and upstream energy consumption for each fuel within the mode. Outputs are summaries of end-use energy consumption, full-fuel cycle GHG emissions, and upstream energy consumption associated with each end-use fuel.

In NEAT's current form, the user can evaluate changes in ton-miles of an individual commodity, changes in mode share for all or selected commodities, changes in energy intensities for all or selected commodities, and changes in the use of alternative fuels, including electricity, by freight mode. Although the amount of electricity used for powering non-light-duty transportation is small comparing with other fuels, the user can evaluate the effects on GHG emissions and upstream energy use of changes in the electricity-generation fuel mix.

2 BASE CASE DATA

Base case ton-mile and mode share data were obtained from the U.S. Department of Transportation's Freight Analysis Framework (FAF) database (version 4.0; DOT 2017). The FAF 4.0 analytical tool was used to derive total estimated ton-miles by mode within commodity for the years 2007, 2012, 2015, 2020, 2025, 2030, 2035, 2040, and 2045. FAF data are provided in seven domestic mode categories:

- truck
- rail
- marine
- aviation (includes truck-air)
- multiple modes
- pipeline
- other and unknown

Table 1 shows FAF 4.0 ton-mile totals by commodity and Table 2 shows commodity flow totals by FAF mode.

Ton-miles for FAF's "multiple modes" and "other and unknown" categories need to be assigned to known modes for use in NEAT. Since freight aviation includes truck components and the pipeline mode is not likely to be a part of a multimodal shipment, we assigned multimode ton-miles to truck, rail, and domestic marine modes.

The truck share of multimode ton-miles is now dependent on commodity, as shown in Table 3, instead of being a flat share as was assumed in the earlier version of NEAT. The remaining multimode ton-miles were prorated among "rail" and "marine." After the assignment of multimodal ton-miles, other and unknown mode ton-miles were prorated among five known modes: truck, rail, domestic marine, air freight, and pipeline. This allocation was used for estimating mode shares by commodity.

2.1 CHANGES TO FREIGHT ANALYSIS FRAMEWORK DATA

FAF data use two-digit SCTG (Standard Classification of Transported Goods) codes and provide estimates for 43 commodities, as listed in Table 1. To reduce data requirements and user burden for defining a scenario, we combined commodities that would typically be shipped in similar ways, reducing the number of commodities to 30. The following SCTG codes are combined in NEAT:

- 02, 03, 04
- 05, 06
- 10, 11, 12
- 17, 18
- 25, 26

- 27, 28, 29
- 32, 33
- 40, 41, 43, 99

More information about what subcommodities are included in these two-digit codes can be obtained from the 2012 Commodity Flow Survey SCTG manual (DOT 2011).

Because NEAT was developed to assess the impacts of alternative scenarios for the U.S. Department of Energy (DOE), FAF projections for selected energy commodities were replaced with projections from DOE's 2017 Annual Energy Outlook (AEO; EIA 2017).

Because the last year of FAF 4.0 projections is 2045, modified FAF projections were extended to 2050.

We added six energy-related commodities:

- corn for ethanol production – SCTG 02200
- biomass for direct combustion and biofuel production – SCTG 03999
- fuel ethanol – SCTG 17600
- natural gas – SCTG 19330
- biofuels – specific codes for various biofuels other than ethanol are not yet assigned[1] (except for biodiesel derived from vegetable oils or animal fats – SCTG 18220)
- hydrogen and rare gases – SCTG 20242

Data for these commodities were estimated by using AEO 2017 projections (EIA 2017).

We separated corn used for ethanol production (SCTG 02200) from cereal grain (SCTG 02). These quantities were estimated by first converting EIA's AEO 2017 projections of fuel ethanol use from British thermal units (Btu) to gallons. From the gallon estimates, corn tonnage was estimated by using corn ethanol yield data (gallons per bushel) in Argonne's GREET model (Argonne 2016). Assuming ethanol processing plants are in corn-producing states, shorter lengths of haul were assigned. The average length of haul was slowly increased, to 50 miles in 2010, 75 miles in 2015, 125 miles in 2020, and 150 miles in 2035. We made sure that one-third of the corn tonnage used for ethanol production was added to SCTG 04 (animal feed) as distiller's grain (USDA 2007), with the longer length of haul.

[1] The 2012 CFS assigns SCTG code 18220 to biodiesel derived from vegetable oils and animal fats only.

TABLE 1 Commodity Flow as Estimated by FAF 4.0 (in million ton-miles)

SCTG Code	Commodity	2012	2015	2020	2025	2030	2035	2040	2045
01	Live animals/fish	18,045	18,055	19,520	20,672	21,854	23,188	24,596	26,120
02	Cereal grains	234,523	268,578	269,146	284,098	304,762	319,519	340,188	358,828
03	Other agricultural products	152,609	165,595	177,951	194,907	211,853	229,042	258,673	290,768
04	Animal feed	103,437	109,686	121,881	134,705	146,359	159,058	175,093	192,109
05	Meat/seafood	51,134	53,591	59,488	65,681	71,869	78,729	87,115	96,632
06	Milled grain products	59,265	61,928	68,658	75,470	82,513	90,149	98,849	108,748
07	Other foodstuff	254,120	268,894	299,843	330,641	363,197	399,397	442,420	487,881
08	Alcoholic beverages	44,451	45,338	52,282	59,745	68,303	78,720	92,280	102,776
09	Tobacco products	781	741	593	487	417	368	324	279
10	Building stone	3,190	12,097	13,356	14,053	14,510	14,903	15,330	16,059
11	Natural sands	57,378	58,474	64,016	69,277	75,711	79,814	85,412	90,629
12	Gravel	123,544	132,515	143,865	149,269	154,298	160,782	169,110	176,115
13	Nonmetallic minerals	55,209	61,479	69,635	74,534	79,377	84,004	89,947	95,571
14	Metallic ores	65,313	61,864	63,543	66,944	69,563	72,195	76,106	80,925
15	Coal	782,602	653,101	568,667	537,433	507,878	494,782	480,572	464,542
16	Crude petroleum	329,297	395,364	423,103	439,503	435,208	424,177	412,501	400,500
17	Gasoline	138,077	154,814	158,226	158,681	160,768	165,912	173,830	180,849
18	Fuel oils	109,174	120,971	127,192	132,971	127,446	123,338	121,205	120,373
19	Other coal and energy products - n.e.c.[a]	699,264	795,097	913,347	995,939	1,059,583	1,124,102	1,179,873	1,238,269
20	Basic chemicals	174,990	181,364	211,828	236,789	256,232	275,245	302,137	325,753
21	Pharmaceuticals	10,344	10,767	12,743	15,216	18,209	21,813	26,436	30,970
22	Fertilizers	85,793	90,902	104,642	115,207	125,109	130,745	135,503	139,424
23	Chemical products	58,854	63,247	75,248	85,489	96,151	108,180	124,671	138,855
24	Plastics/rubber	126,651	138,636	165,388	192,077	221,329	243,552	273,411	305,854
25	Logs	16,874	18,647	21,269	22,287	23,371	24,653	26,120	27,961
26	Wood products	102,646	117,574	136,724	145,508	154,543	157,877	163,302	170,130
27	Newsprint/paper	79,339	67,938	71,085	74,353	77,923	84,167	89,568	98,438
28	Paper articles	30,210	30,862	32,517	34,840	37,404	40,108	43,175	46,711
29	Printed products	18,307	17,348	17,408	17,437	16,584	17,910	19,547	21,296
30	Textiles/leather	38,527	40,287	41,008	41,777	43,740	47,530	54,016	59,944

TABLE 1 (Cont.)

SCTG Code	Commodity	2012	2015	2020	2025	2030	2035	2040	2045
31	Nonmetal mineral products	137,266	154,612	180,676	195,576	212,439	231,814	255,425	283,889
32	Base metals	142,003	151,448	161,173	175,110	187,969	201,449	216,304	229,997
33	Articles - base metal	66,219	70,544	78,806	88,147	97,469	107,381	120,182	134,375
34	Machinery	62,033	65,679	78,680	93,794	110,111	129,618	156,459	184,154
35	Electronics	44,920	48,406	59,207	71,035	84,256	100,097	121,127	140,080
36	Motorized vehicles	94,102	108,894	118,336	126,206	135,028	144,417	155,690	168,025
37	Transport equipment	7,539	8,664	10,381	12,212	14,326	17,176	20,946	24,637
38	Precision instruments	7,330	8,028	9,891	12,265	15,087	18,503	23,321	26,688
39	Furniture	31,201	35,136	43,003	50,407	59,372	70,947	87,651	99,285
40	Misc. manufacturing products	42,278	46,862	52,301	58,478	64,913	72,331	81,565	91,093
41	Waste/scrap	97,141	99,807	111,862	122,377	133,547	146,403	165,583	187,824
43	Mixed freight	98,371	99,019	107,825	114,710	122,806	132,960	145,568	162,339
99	Unknown	1,482	248	269	288	310	337	368	368
	ALL COMMODITIES	4,855,834	5,113,100	5,516,585	5,906,593	6,263,695	6,647,394	7,131,500	7,626,065

[a] Not elsewhere classified.

TABLE 2 Total Commodity Flow by Mode as Estimated by FAF 4.0 (in million ton-miles)

Mode	2012	2015	2020	2025	2030	2035	2040	2045	% Change 2012-2045
Truck	1,894,029	2,029,804	2,241,135	2,423,532	2,604,983	2,798,916	3,042,444	3,298,495	53.47%
Rail	1,467,241	1,412,400	1,411,022	1,462,414	1,517,032	1,582,257	1,673,044	1,764,704	24.88%
Domestic marine	322,015	332,393	355,493	382,040	391,082	396,957	407,660	417,551	43.43%
Freight air (includes truck-air)	5,842	6,230	7,653	9,281	11,081	13,362	16,765	19,552	253.50%
Multiple modes and mail	339,309	358,693	401,967	452,216	508,881	576,239	671,545	764,035	91.13%
Pipeline	820,793	967,096	1,092,253	1,168,984	1,221,454	1,268,919	1,306,961	1,346,108	56.80%
Other and unknown	6,604	6,484	7,060	8,126	9,182	10,744	13,080	15,621	-25.12%
ALL MODES	4,855,834	5,113,100	5,516,585	5,906,593	6,263,695	6,647,394	7,131,500	7,626,065	51.37%

TABLE 3 Approximate Truck Shares of Multimode Commodity Flows

SCTG Code	Commodity	Truck Share	SCTG Code	Commodity	Truck Share
01	Live animals/fish	50%	23	Chemical products	20%
02	Cereal grains	20%	24	Plastics/rubber	25%
03	Other agricultural products	20%	25	Logs	25%
04	Animal feed	20%	26	Wood products	25%
05	Meat/seafood	20%	27	Newsprint/paper	25%
06	Milled grain products	20%	28	Paper articles	35%
07	Other foodstuff	20%	29	Printed products	50%
08	Alcoholic beverages	25%	30	Textiles/leather	50%
09	Tobacco products	25%	31	Nonmetal mineral products	25%
10	Building stone	25%	32	Base metals	25%
11	Natural sands	25%	33	Articles - base metal	25%
12	Gravel	25%	34	Machinery	25%
13	Nonmetallic minerals	20%	35	Electronics	50%
14	Metallic ores	15%	36	Motorized vehicles	25%
15	Coal	15%	37	Transport equipment	20%
16	Crude petroleum	15%	38	Precision instruments	50%
17	Gasoline	15%	39	Furniture	50%
18	Fuel oils	15%	40	Misc. manufacturing products	25%
19	Other coal and energy products - n.e.c.[a]	25%	41	Waste/scrap	25%
20	Basic chemicals	20%	43	Mixed freight	50%
21	Pharmaceuticals	50%	99	Unknown	50%
22	Fertilizers	20%			

[a] Not elsewhere classified.

We separated biomass for energy use (SCTG 03999) from other agricultural products (SCTG 03). Estimated by using EIA's AEO 2017 projections, these quantities represented the sum of biomass used for direct combustion and for producing biofuels. Biomass quantities for biofuels production were estimated by using cellulosic ethanol and biomass-to-liquid projections from AEO in Btu and converting them to gallons by using higher heating values of these fuels. Gallon values were converted to biomass tons by using yield rates (gallons per dry ton) from the GREET model. A shorter length of haul, increasing from 50 miles in 2010 to 80 miles in 2030 (and later), was assigned to biomass.

We estimated fuel ethanol (SCTG 17600) and biofuel ton-miles by using fuel ethanol and biofuel projections in the AEO 2017 and our estimated lengths of haul. AEO's energy projections were converted to tonnage by using higher heating values and densities. We used natural gas use projections in the AEO 2017, converted the projected values to tonnage by using higher heating values and densities, and estimated ton-miles by using the SCTG 19 length of

haul. We reduced SCTG 19 ton-miles by subtracting natural gas and biofuel ton-miles. The AEO 2017 does not project any significant quantity of hydrogen use. Because we assume most of the AEO-projected small quantities will be produced at refueling stations, we estimated very low (placeholder) ton-miles for hydrogen.

For coal (SCTG 15), we used AEO 2017 projections with FAF average length of haul and estimated ton-miles. We followed the same procedure for estimating crude petroleum (SCTG 16) ton-miles. For gasoline (SCTG 17) and fuel oil (SCTG 18), the same quantity are carried by more than one mode. Thus, if EIA's projections were used for estimating tonnage, the quantities needed to be multiplied by a factor greater than 1 to account for multimode transportation. We estimated a factor of 1.7 by using 2012 Commodity Flow Survey (CFS) data (DOT et al. 2011) and arrived at total ton-miles for the years of interest.

Finally, all FAF 4.0 commodity flows were extended to 2050 by using average annual growth in ton-miles between 2040 and 2045. The resulting ton-miles by commodity group are listed in Table 4. The total ton-miles in Table 4 are slightly different than the total ton-miles in Table 1 because the AEO 2017 projections are used for energy commodities. Although we made reasonable assumptions based on literature review, the user should understand that other data may exist that are more recent or better serve user needs.

2.2 TRANSPORT MODE SHARES

We used FAF estimates of mode shares for commodities that were not changed. Although we changed ton-miles for coal and crude petroleum, we assumed that mode shares estimated by FAF were still applicable. We reduced pipeline-mode ton-miles for SCTG 19 by subtracting natural gas ton-miles and computed revised mode shares.

We assumed that all corn used in ethanol production would be transported by truck through 2015. We assigned slowly increasing shares by the rail mode beginning in 2016. The estimated ton-mile shares were:

- 2020: 2.45%
- 2025: 4.81%
- 2030: 8.18%
- 2035: 11.36%
- 2040: 13.39%
- 2045: 15.35%
- 2050: 17.24%

It should be noted that these shares are for ton-miles and they account for differences in length of haul between truck and rail. Because rail usually transports shipments over longer distances, sometimes 4 to 5 times the length of haul by truck, rail's ton-mile share is greater than its tonnage share. All biomass was assumed to be transported by trucks.

TABLE 4 Base Case Ton-Miles by Commodity after Update with Annual Energy Outlook Data (Millions)

SCTG Code	Commodity	2012	2015	2020	2025	2030	2035	2040	2045	2050
01	Live animals/fish	18,045	18,055	19,520	20,672	21,854	23,188	24,596	26,120	27,644
02-04	Cereal grain, other ag product and animal feed	489,870	542,887	565,963	606,488	653,220	696,732	761,635	829,095	896,713
02200	Corn for ethanol production (from cereal grain)	8,443	9,783	10,879	11,477	11,638	11,698	12,071	12,222	12,372
03999	Biomass for biofuels production (from ag product)	7,301	7,455	9,088	12,552	14,683	15,649	16,995	17,550	18,104
05	Meat and seafood	51,134	53,591	59,488	65,681	71,869	78,729	87,115	96,632	106,149
06-07	Milled grain product and other foodstuff	313,385	330,822	368,501	406,111	445,710	489,546	541,269	596,629	651,989
08	Alcoholic beverage	44,451	45,338	52,282	59,745	68,303	78,720	92,280	102,776	113,272
09	Tobacco product	781	741	593	487	417	368	324	279	234
10-12	Building stone, natural sands and gravel	184,112	203,087	221,237	232,599	244,519	255,498	269,852	282,803	295,755
13	Nonmetallic minerals	55,209	61,479	69,635	74,534	79,377	84,004	89,947	95,571	101,194
14	Metallic ores	65,313	61,864	63,543	66,944	69,563	72,195	76,106	80,925	85,744
15	Coal	680,010	635,854	590,531	534,563	478,845	463,579	453,836	446,204	438,572
16	Crude petroleum	635,142	578,278	505,515	529,345	540,911	566,368	621,329	651,254	681,179
17-18	Gasoline and fuel oil	209,633	237,410	248,783	253,099	250,626	258,572	279,216	301,330	323,443
17600	Fuel ethanol	16,456	19,961	21,208	21,846	22,496	22,595	23,048	23,000	22,952
19	Coal n.e.c.[a] (excluding natural gas and biofuels)	180,225	197,830	222,259	238,465	245,181	260,142	273,574	288,063	302,552
19330	Natural gas	593,181	595,840	688,164	754,251	810,945	860,208	902,504	946,415	990,199
	Biofuels[b]	575	1,427	2,923	3,224	3,457	3,753	3,796	3,792	3,787
20	Basic chemicals (excluding H_2)	174,990	181,364	211,828	236,789	256,232	275,245	302,137	325,753	349,368
20242	H_2, N, O_2 and rare gases									
21	Pharmaceuticals	10,344	10,767	12,743	15,216	18,209	21,813	26,436	30,970	35,504
22	Fertilizers	85,793	90,902	104,642	115,207	125,109	130,745	135,503	139,424	143,346
23	Chemical products	58,854	63,247	75,248	85,489	96,151	108,180	124,671	138,855	153,039
24	Plastics & rubber	126,651	138,636	165,388	192,077	221,329	243,552	273,411	305,854	338,297
25-26	Logs and wood products	119,520	136,221	157,993	167,795	177,914	182,530	189,422	198,091	206,760

TABLE 4 (Cont.)

SCTG Code	Commodity	2012	2015	2020	2025	2030	2035	2040	2045	2050
27-29	Newsprint/paper, paper articles & printed matter	127,857	116,148	121,010	126,630	131,911	142,186	152,290	166,446	180,603
30	Textile and leather	38,527	40,287	41,008	41,777	43,740	47,530	54,016	59,944	65,872
31	Nonmetallic mineral products	137,266	154,612	180,676	195,576	212,439	231,814	255,425	283,889	312,352
32-33	Base metals and their articles	208,222	221,992	239,980	263,256	285,438	308,830	336,486	364,373	392,259
34	Machinery	62,033	65,679	78,680	93,794	110,111	129,618	156,459	184,154	211,849
35	Electronics	44,920	48,406	59,207	71,035	84,256	100,097	121,127	140,080	159,033
36	Motorized vehicles	94,102	108,894	118,336	126,206	135,028	144,417	155,690	168,025	180,360
37	Transportation equipment	7,539	8,664	10,381	12,212	14,326	17,176	20,946	24,637	28,328
38	Precision instruments	7,330	8,028	9,891	12,265	15,087	18,503	23,321	26,688	30,055
39	Furniture	31,201	35,136	43,003	50,407	59,372	70,947	87,651	99,285	110,918
40-99	Misc manufacturing products, waste/scrap, mixed freight and unknown	239,273	245,935	272,258	295,853	321,576	352,031	393,084	441,625	490,165
	ALL COMMODITIES	5,127,689	5,276,619	5,622,386	5,993,667	6,341,841	6,766,759	7,337,568	7,898,750	8,449,403

[a] Not elsewhere classified.

[b] Detailed codes are not available for biofuels excluding ethanol. The 2012 CFS assigns SCTG code 18220 to biodiesel from vegetable oils and animal fat only. AEO projects use of additional biofuels.

According to the U.S. Department of Agriculture, 60% of the fuel ethanol tonnage is currently moved by rail, 30% by truck, and 10% by barge (USDA 2007). We assumed rail and domestic water to have 5 times the length of haul of trucks. We slowly increased tonnage moved by truck to 30.7% and by rail to 60.3%, thereby reducing domestic water tonnage to 9%. The resulting ton-mile mode shares for the truck mode were:

- 2015: 7.89%
- 2020: 8.06%
- 2025: 8.09%
- 2030: 8.10%
- 2035 & beyond: 8.12%

The rail mode ton-mile shares were:

- 2015: 78.95%
- 2020: 79.37%
- 2025: 79.67%
- 2030: 79.78%
- 2035: 79.85%
- 2040 & beyond: 79.95%

We assumed biofuel ton-miles being shared equally by truck and rail in 2011. The rail ton-mile share will increase to 73.95% by 2020 and reach 79.35% by 2025. The rail share will remain between 79.35% and 79.95% through 2050. The truck share will decrease to 17.9% by 2015 and further down to 8.1% by 2020. The truck share will remain at that level through 2050. Table 5 lists the base case mode shares.

2.3 ENERGY INTENSITIES OF TRANSPORT MODES

We developed commodity-level energy intensity estimates for each freight mode, as described in Sections 2.3.1 through 2.3.5.

2.3.1 Rail

For the rail mode, we used 2012 commodity group tonnage and carloads data from the Association of American Railroads' *Railroad Facts 2013* (AAR 2013). From the same publication, we used total 2012 fuel use, total 2012 ton-miles, and average tons per car to compute average fuel use per car-mile. We converted fuel-use per car-mile to Btu per car-mile by using the higher heating value of diesel fuel. Commodity group tonnage and number of carloads were used for computing average tons per car for each commodity group. These average tons per car and average Btu per car-mile gave us the first estimates of rail mode Btu per ton-mile by commodity group.

TABLE 5 Base Case Transport Mode Shares by Commodity

SCTG Code	Commodity	Mode	2012	2015	2020	2025	2030	2035	2040	2045	2050
01	Live animals and fish	Truck	99.2%	99.6%	99.6%	99.5%	99.5%	99.5%	99.5%	99.5%	99.5%
		Rail	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
		Dom marine	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Air freight	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
02-04	Cereal grain, other agriculture product and animal feed	Truck	48.1%	47.5%	48.0%	47.7%	47.5%	47.5%	47.4%	47.5%	47.6%
		Rail	43.4%	44.0%	43.5%	43.9%	44.2%	44.4%	44.6%	44.7%	44.8%
		Dom marine	8.2%	8.3%	8.2%	8.1%	8.1%	7.9%	7.7%	7.5%	7.3%
		Air freight	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
02200	Corn for ethanol production (from cereal grain)	Truck	100.0%	100.0%	97.6%	95.2%	91.8%	88.6%	86.6%	86.6%	84.7%
		Rail	0.0%	0.0%	2.5%	4.8%	8.2%	11.4%	13.4%	13.4%	15.4%
		Dom marine	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
03999	Biomass (from other agriculture prod)	Truck	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
		Rail	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Dom marine	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
05	Meat and seafood	Truck	93.5%	93.8%	93.7%	93.4%	93.1%	92.8%	92.3%	91.8%	91.4%
		Rail	4.6%	4.5%	4.6%	4.8%	5.0%	5.2%	5.5%	5.8%	6.0%
		Dom marine	1.6%	1.4%	1.4%	1.5%	1.5%	1.6%	1.8%	1.9%	2.0%
		Air freight	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.5%	0.5%	0.5%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
06-07	Milled grain product and other foodstuff	Truck	71.4%	71.5%	71.4%	71.2%	70.9%	70.5%	70.0%	69.5%	69.1%
		Rail	27.8%	27.5%	27.6%	27.8%	28.0%	28.4%	28.8%	29.2%	29.6%
		Dom marine	0.8%	0.9%	1.0%	1.0%	1.0%	1.1%	1.2%	1.2%	1.3%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

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TABLE 5 (Cont.)

SCTG Code	Commodity	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
08	Alcoholic beverages (excluding fuel ethanol)	Truck	58.8%	60.6%	59.3%	58.2%	56.9%	55.5%	53.7%	52.9%	52.2%
		Rail	37.5%	39.0%	40.2%	41.3%	42.5%	43.9%	45.6%	46.4%	47.0%
		Dom marine	3.6%	0.4%	0.5%	0.5%	0.6%	0.6%	0.7%	0.7%	0.7%
		Air freight	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
09	Tobacco products	Truck	87.0%	89.9%	89.5%	89.1%	89.1%	89.4%	89.4%	89.1%	88.7%
		Rail	12.0%	7.6%	7.9%	8.1%	8.1%	7.9%	7.8%	8.0%	8.2%
		Dom marine	0.1%	2.6%	2.7%	2.8%	2.8%	2.8%	2.8%	2.9%	3.0%
		Air freight	0.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
10-12	Building stone, natural sands and gravel	Truck	66.0%	63.8%	63.6%	64.1%	64.3%	64.6%	64.9%	65.1%	65.3%
		Rail	16.4%	24.3%	24.4%	24.3%	24.4%	24.4%	24.4%	24.5%	24.6%
		Dom marine	17.5%	11.8%	11.9%	11.6%	11.2%	11.0%	10.6%	10.3%	10.1%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
13	Nonmetallic minerals	Truck	56.9%	44.3%	44.6%	44.7%	44.9%	45.4%	45.7%	46.0%	46.3%
		Rail	31.1%	36.2%	36.0%	36.6%	36.9%	37.1%	37.5%	37.8%	38.1%
		Dom marine	12.0%	18.0%	17.9%	17.4%	16.9%	16.2%	15.5%	14.9%	14.3%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	1.4%	1.4%	1.3%	1.3%	1.3%	1.3%	1.3%	1.3%
14	Metallic ores	Truck	15.8%	13.5%	13.8%	14.3%	14.8%	15.8%	16.6%	17.7%	18.7%
		Rail	58.0%	67.8%	67.3%	66.9%	66.3%	65.7%	65.3%	64.8%	64.3%
		Dom marine	26.3%	18.7%	18.9%	18.9%	18.8%	18.5%	18.1%	17.5%	17.0%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15	Coal	Truck	5.3%	5.8%	6.4%	6.8%	7.3%	7.6%	8.2%	8.8%	9.4%
		Rail	92.6%	90.7%	89.8%	88.9%	88.0%	87.3%	86.1%	85.1%	84.1%
		Dom marine	2.1%	3.5%	3.8%	4.3%	4.7%	5.2%	5.6%	6.0%	6.5%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

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TABLE 5 (Cont.)

SCTG Code	Commodity	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
16	Crude petroleum	Truck	1.0%	2.0%	1.9%	1.8%	1.8%	1.7%	1.6%	1.6%	1.5%
		Rail	0.2%	10.5%	9.1%	8.6%	7.9%	7.3%	6.9%	6.6%	6.2%
		Dom marine	26.7%	29.6%	28.9%	30.0%	30.2%	30.6%	31.0%	31.3%	31.5%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	72.1%	57.9%	60.1%	59.5%	60.1%	60.4%	60.5%	60.6%	60.7%
17-18	Gasoline and fuel oil	Truck	45.2%	36.2%	35.6%	34.8%	34.0%	33.5%	32.6%	31.8%	31.0%
		Rail	1.9%	18.3%	18.9%	19.8%	21.9%	24.7%	28.0%	30.5%	33.0%
		Dom marine	20.5%	20.3%	21.1%	21.6%	20.2%	18.5%	17.2%	16.7%	16.1%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	32.4%	25.1%	24.4%	23.9%	23.9%	23.3%	22.2%	21.0%	19.9%
17600	Fuel ethanol	Truck	7.9%	7.9%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%	8.1%
		Rail	79.0%	79.0%	79.4%	79.7%	79.8%	79.9%	80.0%	80.0%	80.0%
		Dom marine	13.2%	13.2%	12.6%	12.2%	12.1%	12.0%	11.9%	11.9%	11.9%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
19	Coal n.e.c[a] excluding natural gas and biofuels	Truck	13.7%	13.9%	14.3%	14.5%	14.7%	14.7%	14.6%	14.4%	14.3%
		Rail	12.4%	5.5%	5.4%	5.2%	5.1%	5.0%	4.9%	5.0%	5.1%
		Dom marine	15.0%	3.3%	3.3%	3.3%	3.3%	3.3%	3.4%	3.3%	3.3%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	58.9%	77.3%	76.9%	77.0%	76.9%	77.0%	77.1%	77.3%	77.4%
19330	Natural gas	Truck	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Rail	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Dom marine	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Biofuels[b]	Truck	62.5%	25.8%	17.9%	12.5%	12.3%	12.2%	12.2%	12.2%	12.0%
		Rail	37.5%	66.0%	74.0%	79.4%	79.5%	79.6%	79.6%	79.6%	79.8%
		Dom marine	0.0%	8.2%	8.2%	8.2%	8.2%	8.2%	8.2%	8.2%	8.2%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

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TABLE 5 (Cont.)

SCTG Code	Commodity	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
20	Basic chemicals (excluding H_2)	Truck	37.5%	32.8%	32.8%	32.5%	32.2%	31.9%	31.4%	31.2%	31.0%
		Rail	49.1%	53.7%	53.7%	54.1%	54.5%	55.1%	55.8%	56.1%	56.4%
		Dom marine	11.4%	10.7%	10.7%	10.6%	10.4%	10.2%	9.9%	9.8%	9.8%
		Air freight	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
		Pipeline	2.0%	2.6%	2.7%	2.7%	2.7%	2.7%	2.7%	2.6%	2.6%
20242	H_2, N, O_2 and rare gases	Truck	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Rail	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Dom marine	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
21	Pharmaceuticals	Truck	77.6%	81.7%	80.6%	79.6%	78.7%	77.7%	76.5%	76.2%	76.0%
		Rail	18.2%	10.2%	10.7%	11.1%	11.6%	12.0%	12.6%	12.8%	12.9%
		Dom marine	0.8%	6.8%	7.4%	7.8%	8.2%	8.7%	9.2%	9.3%	9.4%
		Air freight	3.4%	1.3%	1.4%	1.5%	1.5%	1.6%	1.7%	1.7%	1.7%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
22	Fertilizers	Truck	38.8%	30.7%	32.1%	31.5%	30.6%	30.5%	30.4%	30.3%	30.2%
		Rail	55.9%	58.3%	56.9%	56.4%	56.1%	56.1%	56.2%	56.4%	56.6%
		Dom marine	5.3%	9.7%	9.8%	10.8%	12.0%	12.2%	12.2%	12.2%	12.1%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	1.2%	1.2%	1.2%	1.3%	1.2%	1.2%	1.1%	1.0%
23	Chemical products	Truck	78.7%	78.9%	78.4%	77.8%	77.2%	76.5%	75.5%	75.0%	74.7%
		Rail	19.4%	19.8%	20.1%	20.5%	20.9%	21.4%	22.0%	22.3%	22.5%
		Dom marine	1.2%	1.0%	1.1%	1.2%	1.4%	1.7%	2.0%	2.1%	2.3%
		Air freight	0.6%	0.3%	0.3%	0.4%	0.4%	0.4%	0.5%	0.5%	0.5%
		Pipeline	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
24	Plastics and rubber	Truck	63.1%	56.6%	55.7%	54.1%	52.5%	52.3%	52.2%	52.1%	52.0%
		Rail	36.4%	42.7%	43.5%	45.0%	46.6%	46.7%	46.8%	46.8%	46.8%
		Dom marine	0.2%	0.6%	0.6%	0.6%	0.6%	0.7%	0.8%	0.9%	1.0%
		Air freight	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%	0.3%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

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TABLE 5 (Cont.)

SCTG Code	Commodity	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
25-26	Logs and wood products	Truck	74.9%	70.2%	69.6%	68.7%	67.9%	66.8%	65.4%	63.9%	62.5%
		Rail	24.9%	29.2%	29.7%	30.5%	31.2%	32.2%	33.4%	34.8%	36.1%
		Dom marine	0.2%	0.6%	0.7%	0.8%	0.9%	1.0%	1.1%	1.3%	1.4%
		Air freight	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
27-29	Newsprint/paper, paper articles and printed matter	Truck	64.5%	69.8%	69.4%	68.9%	68.4%	68.1%	67.8%	67.5%	67.2%
		Rail	35.1%	29.0%	29.4%	29.7%	30.2%	30.4%	30.6%	30.8%	31.0%
		Dom marine	0.3%	1.0%	1.1%	1.2%	1.2%	1.3%	1.4%	1.5%	1.5%
		Air freight	0.2%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
30	Textiles and leather	Truck	75.8%	81.8%	79.8%	77.6%	75.4%	73.4%	71.4%	70.2%	69.3%
		Rail	22.4%	13.7%	14.9%	16.2%	17.5%	18.7%	19.9%	20.6%	21.2%
		Dom marine	0.1%	3.5%	4.2%	5.0%	5.7%	6.4%	7.1%	7.4%	7.7%
		Air freight	1.7%	1.0%	1.1%	1.3%	1.4%	1.5%	1.6%	1.7%	1.8%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
31	Nonmetallic mineral products	Truck	83.1%	79.1%	79.2%	79.0%	78.6%	78.1%	77.4%	77.0%	76.6%
		Rail	11.6%	16.3%	16.2%	16.3%	16.6%	17.0%	17.6%	17.9%	18.2%
		Dom marine	5.2%	4.6%	4.6%	4.6%	4.7%	4.8%	4.9%	5.0%	5.0%
		Air freight	0.1%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
32-33	Base metals and their articles	Truck	69.1%	71.6%	71.4%	71.4%	71.4%	71.3%	71.2%	71.1%	71.0%
		Rail	28.2%	23.5%	23.5%	23.3%	23.2%	23.2%	23.2%	23.3%	23.4%
		Dom marine	2.4%	4.7%	4.9%	5.1%	5.2%	5.3%	5.4%	5.4%	5.3%
		Air freight	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.3%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
34	Machinery	Truck	81.3%	79.0%	78.1%	77.4%	76.7%	75.8%	74.8%	74.2%	73.8%
		Rail	16.0%	18.1%	18.9%	19.3%	19.9%	20.6%	21.5%	22.0%	22.3%
		Dom marine	0.1%	2.1%	2.2%	2.3%	2.4%	2.5%	2.7%	2.7%	2.8%
		Air freight	2.6%	0.8%	0.9%	0.9%	1.0%	1.0%	1.1%	1.1%	1.1%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

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TABLE 5 (Cont.)

SCTG Code	Commodity	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
35	Electronics	Truck	77.5%	83.7%	82.9%	82.3%	81.5%	80.7%	79.6%	79.1%	78.7%
		Rail	17.8%	11.5%	12.0%	12.4%	12.8%	13.4%	14.0%	14.4%	14.7%
		Dom marine	1.6%	2.3%	2.5%	2.6%	2.7%	2.9%	3.0%	3.1%	3.2%
		Air freight	3.2%	2.5%	2.6%	2.8%	2.9%	3.1%	3.3%	3.4%	3.5%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
36	Motorized vehicles	Truck	66.6%	70.1%	69.1%	68.4%	67.7%	66.8%	65.6%	64.6%	63.8%
		Rail	32.9%	29.1%	30.1%	30.7%	31.5%	32.4%	33.5%	34.5%	35.3%
		Dom marine	0.1%	0.5%	0.5%	0.5%	0.5%	0.5%	0.6%	0.6%	0.6%
		Air freight	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
37	Transportation equipment	Truck	60.9%	51.5%	51.4%	51.1%	51.0%	51.0%	51.0%	51.0%	51.1%
		Rail	36.0%	37.6%	37.0%	36.5%	36.0%	35.5%	35.2%	35.0%	34.9%
		Dom marine	0.6%	8.5%	9.2%	10.0%	10.7%	11.2%	11.5%	11.6%	11.6%
		Air freight	2.5%	2.4%	2.3%	2.3%	2.3%	2.3%	2.4%	2.4%	2.4%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
38	Precision instrument	Truck	60.2%	76.1%	75.4%	74.6%	73.8%	72.8%	71.4%	71.2%	71.0%
		Rail	29.6%	15.5%	16.0%	16.4%	16.8%	17.3%	17.9%	18.0%	18.2%
		Dom marine	0.4%	2.9%	3.0%	3.1%	3.2%	3.3%	3.4%	3.4%	3.5%
		Air freight	9.8%	5.4%	5.6%	6.0%	6.2%	6.6%	7.3%	7.3%	7.4%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
39	Furniture	Truck	81.3%	87.9%	86.6%	84.9%	83.1%	81.2%	79.1%	78.4%	77.9%
		Rail	18.3%	9.5%	10.5%	11.7%	12.9%	14.3%	15.8%	16.3%	16.7%
		Dom marine	0.1%	2.3%	2.7%	3.2%	3.7%	4.2%	4.8%	5.0%	5.1%
		Air freight	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
40-99	Misc manufacturing product, waste/scrap, mixed freight and unknown	Truck	84.1%	83.4%	82.8%	82.0%	81.2%	80.3%	78.9%	77.7%	76.7%
		Rail	14.0%	13.1%	13.6%	14.2%	14.8%	15.5%	16.6%	17.6%	18.3%
		Dom marine	1.7%	3.4%	3.5%	3.6%	3.8%	4.0%	4.3%	4.6%	4.8%
		Air freight	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.2%	0.2%
		Pipeline	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

[a] Not elsewhere classified.

[b] Detailed codes are not available for biofuels excluding ethanol. The 2012 CFS assigns SCTG code 18220 to biodiesel from vegetable oils and animal fats only. AEO projects use of additional biofuels.

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Next, we used average rail length of haul for each commodity group from the 2012 Commodity Flow Survey (CFS 2015) and computed ton-miles. The resulting ton-mile total was lower than the total ton-miles reported in *Railroad Facts 2013*. We prorated the difference and computed total diesel use by using the first energy intensity estimates. We adjusted the first energy intensity estimates to match total diesel use reported in *Railroad Facts 2013.* From these 2012 energy intensity estimates, we developed 2010 rail mode energy intensity values by commodity such that when applied to FAF 4.0 ton-mile values for the year 2010 (interpolated from FAF 4.0), the rail mode energy consumption would match the 2010 freight railroad energy use data reported in the TEDB (Davis et al. 2012).

2.3.2 Truck

For the truck mode, we used the 2002 Vehicle Inventory and Use Survey (VIUS 2005) and 2002 CFS (DOT 2004) and developed 2002 energy intensity estimates. Combination truck data from the 2002 VIUS were selected and summarized by primary product carried. This summary provided vehicle miles of travel (VMT), VMT when no load was carried, ton-miles when loaded, and fuel use, all by primary product. From these data, we computed commodity-level miles per gallon (MPG) and average load when loaded. The summary also provided the average MPG for all commodities. The 2002 CFS data provided commodity-level tonnage as well as ton-miles for truck only, truck and rail, and truck and water modes.

To separate truck ton-miles from truck-rail and truck-water movements, we assumed 100 miles on truck mode for multimode tonnage and computed total ton-miles for truck. We applied average load and percent VMT with no load from the VIUS summary to arrive at the commodity-level VMT. The resulting total VMT were lower than the value published in *Highway Statistics 2002* (FHWA 2003). We applied a factor to each commodity VMT to match the total in *Highway Statistics 2002*. By using the commodity-level average MPG, we computed truck mode fuel use for each commodity and converted the value to commodity-level energy intensity in Btu per ton-mile. For ton-mile computations, we used percent of VMT when loaded and average loading from VIUS. These 2002 energy intensities were revised such that when applied to 2012 ton-miles (interpolated from FAF 4.0) the resulting heavy truck energy use was equal to 85% of class 7 and class 8 heavy truck energy consumption in the TEDB (Davis et al. 2014).

2.3.3 Domestic Marine

For the marine mode, we had only total marine freight energy consumption (Davis et al. 2012, 2014, 2016). EIA provides separate energy consumption estimates for domestic marine and ocean-going marine in its AEO 2017. We used the domestic marine share in 2015 together with 2015 marine freight energy use in the TEDB to estimate domestic marine freight energy use. We first applied a factor to the rail mode's commodity-level energy intensity and then adjusted some commodity energy intensities. We lowered the energy intensities for less-time-sensitive commodities such as waste, scrap, and unknown. We ensured that the 2015 energy

intensities, when applied to the 2015 commodity ton-miles, resulted in energy use that matched with earlier estimated domestic marine energy use.

2.3.4 Air Freight

For air freight, we assumed 10% of domestic aviation energy use would be for freight. First we estimated the total 2015 air freight energy use from the TEDB. We applied a fixed factor to rail energy intensities so that the resulting energy intensities, when applied to 2010 air freight ton-miles, would result in total air-freight energy use that matched with our earlier estimate.

2.3.5 Pipeline

Data relating to energy use by pipelines are not readily available. For our modeling purpose, this energy use was subdivided as energy use by natural gas pipelines and energy use by all other pipelines. Natural gas is transported through pipelines pushed by compressors that are located at regular intervals. Most of these compressors are powered by internal combustion engines (ICE) or turbines that use natural gas as fuel. EIA collects data relating to natural gas use by natural gas pipeline compressors. Some natural gas pipeline compressors use electricity. Although a small number of pumping stations for pipelines other than natural gas pipelines are diesel engine driven, their energy use is negligible. For our analysis, we assumed that all pipelines other than natural gas pipelines are using electricity.

Data relating to electricity use by natural gas pipelines is not readily available. Hooker (1981) developed an equation to estimate electricity use by natural gas pipelines. The equation assumes energy use per horsepower (hp) to be equal for both natural-gas-powered and electricity-powered compressors. In 1980, the electric compressor hp share of the total natural gas pipeline compressor hp was 6%. Assuming a motor efficiency of 90% and a natural gas ICE efficiency of 21.15%, a factor of 0.015 was applied to pipeline natural gas energy use in Btu:

Electric Btu = 0.015 × natural gas Btu used by pipeline compressors

The factor 0.015 is computed as:

[(electric hp share = 0.06) / (natural gas hp share = 0.94)] × [(natural gas ICE efficiency = 0.2115) / (electric motor efficiency = 0.9)]

Although the electric hp share of total natural pipeline compressor hp may not have remained constant at 6% since 1980, we could not obtain reliable electric hp and total hp data. We used the 2010 natural gas pipeline energy use estimates from TEDB and 2010 natural gas ton-miles estimated earlier and estimated the 2010 natural gas pipeline energy intensity.

The TEDB 35 (Davis et al. 2016) reports 2014 natural gas and electricity consumption by natural gas pipelines. For 2010, we used Table 2.5 of TEDB 31. We extrapolated the trend

between 2010 and 2014 to 2015 to develop the 2015 control totals. The energy consumption estimates for natural gas pipelines in the base case of NEAT matches with the 2010 data and the extrapolated 2015 numbers. Energy consumption data for pipelines that transport commodities other than natural gas are not available. In the absence of reliable information, other pipeline energy use is estimated by using roughly 80% of the rail energy intensity for most liquid commodities.

2.3.6 Future Energy Intensities

We used the AEO 2017 projections for the years 2020, 2025, 2030, 2035, 2040 and 2045 and identified a metric that would indirectly provide the energy intensity change for each non-light-duty mode:

- Truck: change in Btu per mile
- Rail: change in Btu per ton-mile
- Domestic marine: change in Btu per ton-mile
- Aviation mode: change in Btu per revenue seat mile (We assumed its energy intensity would change similarly to that of passenger aviation.)
- Pipeline: change in natural gas use by compressors per thousand cubic feet of natural gas transported

We developed energy intensity multipliers for each mode and applied these multipliers to all commodities. Table 6 is a comprehensive listing of the resulting energy intensity values for each mode within each commodity.

2.4 FUEL SHARES WITHIN TRANSPORT MODE

Each transport mode is capable of using multiple fuels or blends of fuels. Base case fuel shares were derived for each transport mode for input to NEAT. Table 7 lists these.

All fuel share inputs to NEAT, except for pipeline fuel shares, are specified as volumetric share of fuels within mode. Natural gas pipeline energy shares are specified in Btu.

2.4.1 Truck

The truck mode uses petroleum diesel most of the time. It has started using blends of petroleum diesel and biodiesel and is projected to also use blends of petroleum diesel, F-T diesel, and pyrolysis diesel (EIA 2017). Intercity freight trucks use a limited amount of liquefied natural gas (LNG) at present. The National Petroleum Council projected that trucks will increase their use of LNG in coming decades, resulting in a 15–16% share by 2040 (NPC 2012). Although EIA projected shares similar to the National Petroleum Council in the past, its AEO 2017 lowers projected LNG use to less than 3% by 2050.

TABLE 6 Base Case Energy Intensity Values by Transport Mode and Commodity (Btu per Ton-Mile)

SCTG Code	Commodity	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
01	Live animals/fish	Truck	2,061	2,318	2,181	2,041	1,871	1,734	1,667	1,640	1,626
		Rail	278	345	333	320	309	297	286	276	266
		Domestic marine	548	454	433	412	393	375	357	341	326
		Air freight	13,592	19,656	17,187	14,911	13,679	12,843	12,087	11,464	10,983
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
02-04	Cereal grain, other agricultural product and animal feed	Truck	1,686	1,896	1,784	1,669	1,530	1,418	1,364	1,341	1,330
		Rail	229	285	274	264	254	245	236	227	219
		Domestic marine	452	374	357	340	324	309	295	282	269
		Air freight	11,212	16,213	14,177	12,300	11,283	10,594	9,970	9,457	9,060
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
02200	Corn for ethanol production (from cereal grain)	Truck	1,676	1,885	1,773	1,660	1,521	1,410	1,356	1,333	1,322
		Rail	239	297	286	275	265	256	246	237	228
		Domestic marine	473	392	374	356	340	324	309	295	281
		Air freight	11,686	16,899	14,777	12,820	11,760	11,042	10,392	9,856	9,443
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
03602	Cellulosic biomass (from other ag product)	Truck	1,793	2,017	1,897	1,775	1,628	1,509	1,451	1,426	1,414
		Rail	259	321	309	298	287	276	266	256	247
		Domestic marine	510	423	403	384	366	349	333	318	304
		Air freight	12,644	18,285	15,989	13,871	12,725	11,947	11,244	10,665	10,217
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
05	Meat/seafood	Truck	1,881	2,116	1,990	1,862	1,707	1,582	1,522	1,496	1,483
		Rail	307	382	368	354	341	329	316	305	294
		Domestic marine	606	502	479	456	435	415	396	378	361
		Air freight	15,025	21,727	18,999	16,483	15,120	14,196	13,361	12,672	12,141
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
06-07	Milled grain product and other foodstuff	Truck	1,452	1,633	1,536	1,438	1,318	1,222	1,175	1,155	1,145
		Rail	293	363	350	337	325	313	301	290	280
		Domestic marine	574	476	454	432	412	393	375	358	342
		Air freight	14,314	20,699	18,100	15,703	14,405	13,525	12,729	12,073	11,566
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999

TABLE 6 (Cont.)

SCTG Code	Commodity	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
08	Alcoholic beverage (excluding fuel ethanol)	Truck	1,622	1,825	1,717	1,607	1,473	1,365	1,313	1,291	1,280
		Rail	312	388	373	360	346	334	321	310	298
		Domestic marine	617	511	487	464	443	422	403	384	367
		Air freight	15,262	22,070	19,298	16,743	15,359	14,420	13,572	12,872	12,332
		Pipeline	249	339	275	258	249	245	246	248	249
09	Tobacco product	Truck	1,881	2,116	1,990	1,862	1,707	1,582	1,522	1,496	1,483
		Rail	312	388	373	360	346	334	321	310	298
		Domestic marine	617	511	487	464	443	422	403	384	367
		Air freight	15,262	22,070	19,298	16,743	15,359	14,420	13,572	12,872	12,332
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
10-12	Building stone, natural sands and gravel	Truck	1,505	1,694	1,593	1,491	1,367	1,267	1,218	1,198	1,187
		Rail	220	273	263	253	244	235	226	218	210
		Domestic marine	431	357	340	324	309	295	281	268	256
		Air freight	10,738	15,528	13,578	11,780	10,806	10,146	9,549	9,057	8,677
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
13	Nonmetallic minerals	Truck	1,544	1,737	1,634	1,529	1,402	1,300	1,250	1,229	1,218
		Rail	210	260	251	242	233	224	216	208	200
		Domestic marine	420	348	332	316	302	288	274	262	250
		Air freight	10,264	14,842	12,979	11,260	10,329	9,698	9,127	8,657	8,294
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
14	Metallic ores	Truck	1,622	1,825	1,717	1,607	1,473	1,365	1,313	1,291	1,280
		Rail	210	260	251	242	233	224	216	208	200
		Domestic marine	415	344	328	312	298	284	271	258	247
		Air freight	10,264	14,842	12,979	11,260	10,329	9,698	9,127	8,657	8,294
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
15	Coal	Truck	1,374	1,546	1,454	1,360	1,247	1,156	1,112	1,093	1,084
		Rail	181	224	216	208	200	193	186	179	172
		Domestic marine	356	295	281	268	256	244	232	222	212
		Air freight	8,831	12,771	11,167	9,688	8,888	8,345	7,854	7,449	7,136
		Pipeline	249	339	275	258	249	245	246	248	249

TABLE 6 (Cont.)

SCTG Code	Commodity	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
16	Crude petroleum	Truck	1,442	1,622	1,526	1,428	1,309	1,213	1,167	1,147	1,137
		Rail	229	285	274	264	254	245	236	227	219
		Domestic marine	452	374	357	340	324	309	295	282	269
		Air freight	11,212	16,213	14,177	12,300	11,283	10,594	9,970	9,457	9,060
		Pipeline	184	251	203	191	185	181	182	184	184
17-18	Gasoline and fuel oil	Truck	1,598	1,798	1,691	1,582	1,451	1,345	1,293	1,271	1,260
		Rail	244	303	292	281	271	261	251	242	233
		Domestic marine	484	401	382	364	347	331	316	301	288
		Air freight	11,923	17,242	15,076	13,080	11,999	11,266	10,603	10,056	9,634
		Pipeline	194	264	214	201	194	191	192	194	194
17600	Fuel ethanol	Truck	1,476	1,661	1,562	1,462	1,340	1,242	1,194	1,174	1,164
		Rail	307	382	368	354	341	329	316	305	294
		Domestic marine	606	502	479	456	435	415	396	378	361
		Air freight	15,025	21,727	18,999	16,483	15,120	14,196	13,361	12,672	12,141
		Pipeline	249	339	275	258	249	245	246	248	249
19	Coal n.e.c.[b] excluding natural gas and biofuels	Truck	1,793	2,017	1,897	1,775	1,628	1,509	1,451	1,426	1,414
		Rail	244	303	292	281	271	261	251	242	233
		Domestic marine	484	401	382	364	347	331	316	301	288
		Air freight	11,923	17,242	15,076	13,080	11,999	11,266	10,603	10,056	9,634
		Pipeline	194	264	214	201	194	191	192	194	194
19330	Natural gas	Truck	5,895	6,632	6,237	5,838	5,351	4,960	4,770	4,690	4,650
		Rail	2,069	2,568	2,474	2,383	2,295	2,211	2,130	2,052	1,976
		Domestic marine	2,839	2,352	2,242	2,138	2,038	1,944	1,853	1,769	1,689
		Air freight	42,931	62,082	54,286	47,097	43,204	40,564	38,177	36,209	34,690
		Pipeline	1,219	1,658	1,346	1,263	1,221	1,200	1,205	1,216	1,218
	Biofuels[c]	Truck	1,622	1,825	1,717	1,607	1,473	1,365	1,313	1,291	1,280
		Rail	307	382	368	354	341	329	316	305	294
		Domestic marine	606	502	479	456	435	415	396	378	361
		Air freight	15,025	21,727	18,999	16,483	15,120	14,196	13,361	12,672	12,141
		Pipeline	244	332	269	253	244	240	241	243	244

TABLE 6 (Cont.)

SCTG Code	Commodity	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
20	Basic chemicals (excluding H_2)	Truck	1,676	1,885	1,773	1,660	1,521	1,410	1,356	1,333	1,322
		Rail	239	297	286	275	265	256	246	237	228
		Domestic marine	473	392	374	356	340	324	309	295	281
		Air freight	11,686	16,899	14,777	12,820	11,760	11,042	10,392	9,856	9,443
		Pipeline	192	261	212	199	192	189	190	192	192
20242	H_2, N, O_2 and rare gases	Truck	6,869	7,728	7,268	6,802	6,236	5,780	5,558	5,465	5,418
		Rail	966	1,199	1,155	1,113	1,072	1,033	995	958	923
		Domestic marine	1,898	1,573	1,499	1,429	1,363	1,299	1,239	1,183	1,129
		Air freight	47,218	68,281	59,706	51,800	47,519	44,615	41,989	39,825	38,154
		Pipeline	2,988	4,064	3,299	3,096	2,992	2,941	2,955	2,980	2,985
21	Pharmaceuticals	Truck	1,768	1,990	1,871	1,751	1,605	1,488	1,431	1,407	1,395
		Rail	268	333	321	309	298	287	276	266	256
		Domestic marine	526	436	416	396	378	360	344	328	313
		Air freight	13,118	18,970	16,588	14,391	13,202	12,395	11,666	11,064	10,600
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
22	Fertilizers	Truck	1,846	2,077	1,954	1,828	1,676	1,554	1,494	1,469	1,456
		Rail	239	297	286	275	265	256	246	237	228
		Domestic marine	473	392	374	356	340	324	309	295	281
		Air freight	11,686	16,899	14,777	12,820	11,760	11,042	10,392	9,856	9,443
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
23	Chemical products	Truck	1,627	1,831	1,722	1,611	1,477	1,369	1,317	1,295	1,284
		Rail	239	297	286	275	265	256	246	237	228
		Domestic marine	473	392	374	356	340	324	309	295	281
		Air freight	11,686	16,899	14,777	12,820	11,760	11,042	10,392	9,856	9,443
		Pipeline	181	247	200	188	182	178	179	181	181
24	Plastics and rubber	Truck	1,788	2,011	1,892	1,771	1,623	1,504	1,447	1,423	1,410
		Rail	268	333	321	309	298	287	276	266	256
		Domestic marine	526	436	416	396	378	360	344	328	313
		Air freight	13,118	18,970	16,588	14,391	13,202	12,395	11,666	11,064	10,600
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999

TABLE 6 (Cont.)

SCTG Code	Commodity	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
25-26	Logs and wood products	Truck	1,564	1,759	1,655	1,549	1,420	1,316	1,265	1,244	1,234
		Rail	259	321	309	298	287	276	266	256	247
		Domestic marine	510	423	403	384	366	349	333	318	304
		Air freight	12,644	18,285	15,989	13,871	12,725	11,947	11,244	10,665	10,217
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
27-29	Newsprint/paper, paper articles and printed matter	Truck	1,554	1,748	1,644	1,539	1,411	1,308	1,257	1,237	1,226
		Rail	381	472	455	438	422	407	392	377	364
		Domestic marine	750	621	592	564	538	513	489	467	446
		Air freight	13,448	19,447	17,005	14,753	13,534	12,707	11,959	11,343	10,867
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
30	Textiles and leather	Truck	1,501	1,688	1,588	1,486	1,362	1,263	1,214	1,194	1,184
		Rail	381	472	455	438	422	407	392	377	364
		Domestic marine	750	621	592	564	538	513	489	467	446
		Air freight	13,448	19,447	17,005	14,753	13,534	12,707	11,959	11,343	10,867
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
31	Nonmetallic mineral products	Truck	1,871	2,105	1,979	1,853	1,698	1,574	1,514	1,488	1,476
		Rail	239	297	286	275	265	256	246	237	228
		Domestic marine	473	392	374	356	340	324	309	295	281
		Air freight	14,262	20,624	18,034	15,646	14,353	13,476	12,683	12,029	11,524
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
32-33	Base metals and their articles	Truck	1,549	1,743	1,639	1,534	1,406	1,304	1,254	1,233	1,222
		Rail	259	321	309	298	287	276	266	256	247
		Domestic marine	510	423	403	384	366	349	333	318	304
		Air freight	12,644	18,285	15,989	13,871	12,725	11,947	11,244	10,665	10,217
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
34	Machinery	Truck	1,622	1,825	1,717	1,607	1,473	1,365	1,313	1,291	1,280
		Rail	268	333	321	309	298	287	276	266	256
		Domestic marine	526	436	416	396	378	360	344	328	313
		Air freight	12,088	17,480	15,285	13,261	12,165	11,421	10,749	10,195	9,767
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999

TABLE 6 (Cont.)

SCTG Code	Commodity	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
35	Electronics	Truck	1,569	1,765	1,660	1,553	1,424	1,320	1,269	1,248	1,237
		Rail	278	345	333	320	309	297	286	276	266
		Domestic marine	548	454	433	412	393	375	357	341	326
		Air freight	11,222	16,228	14,190	12,311	11,294	10,604	9,980	9,465	9,068
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
36	Motorized vehicles	Truck	1,720	1,935	1,820	1,703	1,561	1,447	1,392	1,368	1,357
		Rail	1,039	1,290	1,243	1,197	1,153	1,111	1,070	1,031	993
		Domestic marine	1,590	1,317	1,256	1,197	1,141	1,088	1,038	991	946
		Air freight	50,793	73,452	64,228	55,722	51,117	47,993	45,169	42,841	41,043
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
37	Transportation equipment	Truck	1,647	1,853	1,742	1,631	1,495	1,386	1,332	1,310	1,299
		Rail	942	1,169	1,126	1,085	1,045	1,006	969	934	900
		Domestic marine	1,441	1,194	1,138	1,085	1,034	986	940	898	857
		Air freight	9,965	14,410	12,601	10,932	10,028	9,416	8,862	8,405	8,052
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
38	Precision instruments	Truck	2,066	2,324	2,186	2,046	1,875	1,738	1,671	1,644	1,629
		Rail	317	394	379	365	352	339	327	315	303
		Domestic marine	622	515	491	468	447	426	406	388	370
		Air freight	16,540	23,918	20,914	18,145	16,645	15,628	14,708	13,950	13,365
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
39	Furniture	Truck	1,963	2,209	2,077	1,944	1,782	1,652	1,589	1,562	1,549
		Rail	1,000	1,242	1,196	1,152	1,110	1,069	1,030	992	955
		Domestic marine	1,255	1,040	991	945	901	859	819	782	746
		Air freight	12,819	18,538	16,210	14,063	12,901	12,113	11,400	10,812	10,359
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999
40-99	Misc manufacturing products, waste/scrap, mixed freight, and unknown	Truck	1,710	1,924	1,809	1,693	1,552	1,439	1,384	1,361	1,349
		Rail	1,493	1,853	1,785	1,720	1,657	1,596	1,537	1,481	1,426
		Domestic marine	1,872	1,551	1,478	1,409	1,344	1,281	1,221	1,166	1,113
		Air freight	21,445	31,011	27,117	23,526	21,581	20,263	19,070	18,087	17,328
		Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999

[a] A value of 999,999 signifies that the mode is not applicable.

[b] Not elsewhere classified.

[c] Detailed codes are not available for biofuels excluding ethanol. The 2012 CFS assigns SCTG code 18220 to biodiesel from vegetable oils and animal fat only. AEO 2017 projects use of additional biofuels.

TABLE 7 Base Case Fuel Shares by Fuel Type Within Transport Mode

Fuel Type	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050
Diesel	Truck	99.2%	92.9%	89.0%	90.3%	91.1%	90.9%	90.9%	90.8%	90.2%
Biodiesel		0.7%	5.8%	8.0%	4.7%	2.6%	2.8%	2.8%	2.7%	2.6%
Renewable (F-T) diesel		0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.3%	0.2%	0.3%
Pyrolysis diesel		0.0%	0.1%	0.9%	2.6%	4.1%	4.3%	4.2%	3.9%	3.7%
Liquefied natural gas		0.1%	1.2%	2.0%	2.0%	1.9%	1.7%	1.9%	2.4%	3.2%
Diesel	Rail	100.0%	100.0%	99.5%	94.1%	80.1%	67.5%	57.4%	49.2%	42.4%
Renewable (F-T) diesel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pyrolysis diesel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Liquefied natural gas		0.0%	0.0%	0.5%	5.9%	19.9%	32.5%	42.6%	50.8%	57.6%
Diesel (marine)	Domestic marine	92.8%	96.6%	96.6%	96.6%	96.7%	96.7%	96.7%	96.7%	96.7%
Renewable (F-T) diesel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pyrolysis diesel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Liquefied natural gas		0.0%	0.3%	0.9%	1.3%	1.8%	2.2%	2.7%	2.7%	2.7%
Residual fuel oil		7.2%	3.1%	2.6%	2.0%	1.6%	1.1%	0.6%	0.6%	0.6%
Jet fuel	Air freight	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
HR/FT jet fuel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pyrolysis jet fuel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Natural gas	Natural gas pipeline	89.6%	91.6%	91.6%	91.5%	91.5%	91.5%	91.5%	91.4%	91.4%
Electricity		10.4%	8.4%	8.4%	8.5%	8.5%	8.5%	8.5%	8.6%	8.6%

2.4.2 Freight Railroads

Freight railroads currently use petroleum diesel, but could use petroleum diesel blended with F-T and pyrolysis diesel in the future. Freight railroads may also use LNG and electricity in the future. The AEO 2017 projects freight rail LNG use to increase from 0.3% in 2020 to 45.5% in 2050.

2.4.3 Domestic Marine

Domestic marine transport currently uses petroleum diesel, LNG, and residual fuel oil. It, too, could use these petroleum fuels blended with F-T and pyrolysis diesel in the future. AEO 2017 projects domestic marine use of LNG to increase from 0.5% in 2020 to 1.7% in 2050.

2.4.4 Freight Aviation

Freight aviation currently uses petroleum jet fuel. There have been some test flights that used blends of petroleum jet fuel and biomass-based jet fuel. Two types of renewable jet fuels can be blended with petroleum jet fuel, hydroprocessed renewable jet fuel, and pyrolysis jet fuel.

2.4.5 Pipelines

Natural gas pipelines use either natural gas or electricity as compressor fuel. Over 90% of natural gas pipeline compressors are powered by natural gas. All pipelines other than natural gas pipelines are assumed to use electricity to transport commodities.

2.4.6 Future Fuel Shares

EIA projects renewable energy use by the transportation sector in its AEO 2017. We presumed that all renewable diesel fuels would be used by trucks only. We used projections relating to biodiesel, liquid from biomass, and renewable diesel, and developed volumetric shares of combination truck fuel use through 2045. The resulting shares were extended to 2050.

For rail, domestic marine, and freight aviation, we assumed no biofuel use through 2045. We specified modest use of biofuels by these three modes after 2045.

As mentioned earlier, pipeline fuel shares are specified in terms of energy (i.e., Btu). We computed 2014 Btu shares of natural gas pipeline fuels by using end-use energy consumption data in TEDB (Davis et al. 2016). Care was taken to have electricity use in kWh, ignoring conversion losses since the GREET model would account for upstream energy use.

2.5 ELECTRICITY GENERATION SCENARIO

Some natural gas pipeline compressor stations and all other product pipelines use electric energy. The GREET model provides GHG emissions rates and upstream energy use from electricity generation by primary fuel. Within NEAT, five primary fuels are included: coal, petroleum, natural gas, nuclear, and renewables. The base case uses generation shares provided by the AEO 2017 as the AEO Reference Case scenario. The model is also populated with three other electricity generation scenarios: natural gas, nuclear, and renewable. In each of these three scenarios, the dominant fuel (or scenario theme fuel) share is assumed to reach 55% and coal share to drop to 5% by 2050.

Table 8 lists electricity generation by fuel type under the four scenarios.

TABLE 8 Electricity Generation Fuel Shares by Pipeline Mode Scenario

Fuel Type	2010	2015	2020	2025	2030	2035	2040	2045	2050
AEO Reference Case									
Coal	45.0%	33.0%	32.6%	27.8%	23.1%	21.2%	19.5%	17.9%	16.5%
Petroleum	0.9%	0.7%	0.3%	0.3%	0.2%	0.2%	0.2%	0.1%	0.1%
Natural gas	24.1%	32.7%	29.3%	29.6%	33.7%	36.1%	37.5%	38.8%	40.1%
Nuclear	19.7%	19.4%	18.1%	17.9%	17.3%	15.6%	14.5%	12.9%	11.3%
Renewable sources	10.4%	14.1%	19.6%	24.4%	25.7%	26.8%	28.4%	30.2%	32.0%
Natural Gas Scenario									
Coal	45.0%	35.0%	27.9%	19.4%	14.8%	11.5%	7.6%	5.9%	5.0%
Petroleum	0.9%	0.5%	0.4%	0.4%	0.3%	0.2%	0.1%	0.0%	0.0%
Natural gas	24.1%	31.0%	34.0%	38.0%	42.0%	46.0%	50.0%	53.0%	55.0%
Nuclear	19.7%	19.4%	18.1%	17.9%	17.3%	15.6%	14.5%	12.9%	11.3%
Renewable sources	10.4%	14.1%	19.6%	24.4%	25.7%	26.7%	27.8%	28.2%	28.7%
Nuclear Scenario									
Coal	45.0%	36.2%	31.0%	24.2%	21.2%	18.1%	14.1%	8.6%	5.0%
Petroleum	0.9%	0.5%	0.4%	0.4%	0.3%	0.2%	0.1%	0.0%	0.0%
Natural gas	24.1%	29.8%	27.5%	26.0%	24.0%	21.0%	18.0%	16.5%	15.0%
Nuclear	19.7%	19.4%	21.5%	25.0%	30.0%	36.0%	43.0%	50.0%	55.0%
Renewable sources	10.4%	14.1%	19.6%	24.4%	24.6%	24.7%	24.8%	24.9%	25.0%
Renewable Scenario									
Coal	45.0%	36.9%	33.4%	27.6%	22.2%	17.8%	12.9%	8.5%	5.0%
Petroleum	0.9%	0.5%	0.4%	0.4%	0.3%	0.2%	0.1%	0.0%	0.0%
Natural gas	24.1%	28.2%	28.1%	28.2%	28.3%	28.4%	28.5%	28.6%	28.7%
Nuclear	19.7%	19.4%	18.1%	17.9%	17.3%	15.6%	14.5%	12.9%	11.3%
Renewable sources	10.4%	15.0%	20.0%	26.0%	32.0%	38.0%	44.0%	50.0%	55.0%

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3 HOW TO USE NEAT

NEAT is a Microsoft Excel-based computational tool available in one workbook named "YYYY NEAT Working File." Here YYYY represents the year when the file was created. The file is populated with Base Case data and contains Base Case results. This file can be modified by the user to simulate a scenario and saved under a different name. The original file should be kept for comparing Base Case charts with scenario case charts.

3.1 NEAT EXCEL WORKBOOK

The Excel file contains 15 worksheets:

1. **User_Guide** — gives some background information and short instructions on what NEAT is and how it can be used
2. **Model_Input** — user enters input data for his/her scenario
3. **Modal Energy_Results** — summarizes (end use) energy consumption by mode and fuel type with Base Case results on left and user scenario results on right
4. **GHG_Results** — provides summary of full-fuel cycle GHG emissions by mode and fuel type with Base Case results on left and user scenario results on right
5. **Upstream_Energy** — summarizes upstream energy consumption (for feedstock production and for fuel production) by mode and end-use fuel type with Base Case results on left and user scenario results on right
6. **Freight_Data** — contains Base Case data on ton-miles, mode shares, energy intensities, and modal fuel shares
7. **GHG_BTU_Share** — gives GHG emissions rates, upstream energy use rates, and fuel BTU shares by mode and fuel type
8. **Electricity_Gen_Mix** — contains default electricity generation mixes from which the user can select one and later modify
9. **Ton_Miles** — provides ton-miles to be used in all calculations (after incorporating user changes, if any)
10. **Mode_Shares** — gives mode shares to be used in all calculations (after incorporating user changes, if any)
11. **Energy_Intensities** — contains energy intensities to be used in all calculations (after incorporating user changes, if any)
12. **Modal_TMT** — gives calculated ton-miles by commodity and mode after applying ton-mile and mode share changes (if any)
13. **Energy** — provides calculated energy consumption by mode and fuel type summarized as feedstock production energy, fuel production energy, and end-use energy
14. **Carbon_Emissions** — contains calculated values of GHG emissions as carbon dioxide equivalent, summarized as feedstock production emissions, fuel production emissions, and end-use emissions
15. **Charts** — contains charts of major results

3.2 SPECIFYING SCENARIO

The user can design a scenario in the "Model_Input" worksheet. All worksheet cells that are shaded yellow (see Figure 1) can be modified by the user. The worksheet allows for the user to specify a title for the scenario at the top. This title will appear as the scenario title in all summaries relating to end use energy, GHG, and upstream energy.

3.2.1 Ton-Mile Data

The first set of data is ton-mile data by commodity. These data are shown as ton-mile values for 2010, growth factor for 2015 and future growth factors for the years 2020, 2025, 2030, 2035, 2040, 2045, and 2050. The user can either accept the data or change the growth factors for a commodity (or for several commodities) by specifying the first year in which the change takes place in the corresponding cell in column L and the associated factor in column M. New factors for all subsequent years ending in 0 and 5 should be entered in columns D through K, as applicable. Internally, NEAT will use linear interpolation for the intervening years. The growth factor approach is used for ton-miles because a macroeconomic model would provide change indexes by commodity.

Figure 1 shows input instructions and a few commodity rows of ton-mile data input.

	A	B	C	D	E	F	G	H	I	J	K	L	M
5	**COMMODITY TON-MILES (MILLION):** Default ton-miles for 2010 and projected change factors relative to 2010 are listed below. You can either accept these 2010 Ton-Miles and the change factors or change them. The 2010 values are from FHWA's Freight Analysis Framework (FAF) database. To change a 2010 value, please type your estimate in millions of ton-miles. To change values for 2011 through 2050 (factors applied to 2010 data), please type the first year in which your change begins (in column L) and type the corresponding ton-miles (if you are changing 2010 ton-miles) or change factor (for any year after 2010) to be applied to the 2010 value in the next column (column M). For all subsequent years ending in zero or five (columns D through K), please type the change factors to be applied to the 2010 value. (Note: To change ton-miles, you MUST enter a year in column L and the corresponding factor in column M.)												
6			2010	Change Factors Relative to 2010									
7	Commodity	SCTG	Ton-Miles (Million)	2015	2020	2025	2030	2035	2040	2045	2050	1st Yr of change	1st Yr Factor
8	Live Animals/ Fish	01	21,673	0.833	0.901	0.954	1.008	1.070	1.135	1.205	1.276		
9	Cereal Grain, Other Ag Product & Animal Feed	02-04	753,553	0.720	0.751	0.805	0.867	0.925	1.011	1.100	1.190		
10	Corn for Ethanol Production (From Cereal Grain)	02200	7,105	1.377	1.531	1.615	1.638	1.646	1.699	1.720	1.741		
11	Cellulosic Biomass (From Other Ag Product)	03999	7,284	1.023	1.248	1.723	2.016	2.148	2.333	2.409	2.485		
12	Meat/ Seafood	05	51,418	1.042	1.157	1.277	1.398	1.531	1.694	1.879	2.064		
13	Milled Grain Product and Other Food-stuff	06-07	284,762	1.162	1.294	1.426	1.565	1.719	1.901	2.095	2.290		
14	Alcoholic Beverage	08	43,058	1.053	1.214	1.388	1.586	1.828	2.143	2.387	2.631		
15	Fuel Ethanol	17600	16,425	1.215	1.291	1.330	1.370	1.376	1.403	1.400	1.397		
16	Tobacco Product	09	860	0.861	0.690	0.566	0.485	0.429	0.377	0.324	0.272		
17	Building Stone, Natural Sands & Gravel	10-12	338,655	0.600	0.653	0.687	0.722	0.754	0.797	0.835	0.873		
18	Nonmetallic Minerals	13	98,067	0.627	0.710	0.760	0.809	0.857	0.917	0.975	1.032		
19	Metallic Ores	14	81,779	0.756	0.777	0.819	0.851	0.883	0.931	0.990	1.048		
20	Coal	15	780,973	0.814	0.756	0.684	0.613	0.594	0.581	0.571	0.562		

FIGURE 1 Input of Ton-Miles by Commodity

3.2.2 Transport Mode Shares

The process of developing default mode shares was described earlier. Mode shares as percent of ton-miles by five modes are shown for years 2010, 2015, 2020, 2025, 2030, 2035, 2040, 2045, and 2050. The user can either accept the default mode shares or change the mode

share values for one or more than one commodity by specifying the first year in which the change takes place in cells in column L and associated values in column M. New mode shares for all subsequent years ending in 0 and 5 should be entered in columns D through K as applicable. Care should be taken that shares for the five modes sum to 100%. An error flag of "Check sum" will be shown in column O if shares for the five modes in any of the years do not sum to 100%.

Figure 2 shows input instructions for a sampling of commodity rows for mode share input.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
45	**MODE SHARES BY COMMODITY:** Default shares of ton-miles for each major mode are listed below. You can either accept these mode shares or change them. Type the first year in which mode share changes for a commodity and mode combination in column L and corresponding values in column M (both items are required for each mode). Values for all subsequent years ending in zero and five should be entered in columns D through K as applicable. Please note that the shares for all modes within a commodity should add up to 100%. A message of "Check sum" will appear in column O if the sum of mode shares for a commodity in one of the years does not sum to 100%.														
46	**Commodity**	**Mode**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**1st Yr of change**	**1st Yr Share**	**SCTG**	**Error Flag**
47		Truck	96.44%	99.56%	99.55%	99.55%	99.54%	99.53%	99.51%	99.50%	99.49%				
48		Rail	0.17%	0.07%	0.07%	0.07%	0.07%	0.07%	0.07%	0.08%	0.08%				
49	Live Animals/ Fish	Domestic Marine	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%			01	
50		Air Freight	3.36%	0.35%	0.35%	0.35%	0.36%	0.37%	0.39%	0.40%	0.40%				
51		Pipeline	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%				
52		Truck	46.31%	47.55%	48.03%	47.69%	47.45%	47.50%	47.42%	47.50%	47.62%				
53		Rail	33.32%	43.98%	43.55%	43.92%	44.23%	44.35%	44.61%	44.73%	44.80%				
54	Cereal Grain, Other Ag Product & Animal Feed	Domestic Marine	20.30%	8.29%	8.21%	8.15%	8.06%	7.88%	7.68%	7.47%	7.28%			02-04	
55		Air Freight	0.07%	0.18%	0.21%	0.24%	0.25%	0.27%	0.29%	0.30%	0.30%				
56		Pipeline	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%				
57		Truck	100.0%	100.0%	97.55%	95.19%	91.82%	88.64%	86.61%	86.61%	84.65%				
58		Rail	0.00%	0.00%	2.45%	4.81%	8.18%	11.36%	13.39%	13.39%	15.35%				
59	Corn for Ethanol Production (From Cereal Grain)	Domestic Marine	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%			02200	
60		Air Freight	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%				
61		Pipeline	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%				
62		Truck	100.00%	100.0%	100.0%	100.0%	100.0%	100.00%	100.00%	100.00%	100.00%				
63		Rail	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%				
64	Cellulosic Biomass (From Other Ag Product)	Domestic Marine	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%			03999	
65		Air Freight	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%				
66		Pipeline	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%				
67		Truck	92.43%	93.81%	93.65%	93.39%	93.13%	92.80%	92.30%	91.81%	91.41%				
68		Rail	5.60%	4.46%	4.62%	4.79%	4.95%	5.15%	5.49%	5.77%	6.01%				
69	Meat/ Seafood	Domestic Marine	1.70%	1.41%	1.40%	1.46%	1.53%	1.62%	1.76%	1.91%	2.03%			05	
70		Air Freight	0.27%	0.33%	0.34%	0.36%	0.39%	0.42%	0.46%	0.51%	0.55%				
71		Pipeline	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%				

FIGURE 2 Transport Mode Share Input by Commodity

3.2.3 Energy Intensities

Base Case energy intensity values for 2010 and 2015 were developed by researchers at Argonne, as described earlier. The future energy intensities have been estimated by using the rate of improvement projected in the AEO 2017. Energy intensities for the five modes within each commodity are shown for years 2010, 2015, 2020, 2025, 2030, 2035, 2040, 2045, and 2050. If a mode is not applicable to a commodity, a value of 999,999 is entered. The computations of NEAT ignore these high energy intensities and assign zero energy consumption to that mode and commodity combination.

The user can either accept the default energy intensities or modify them. The energy intensity values can be modified three ways: (1) by applying modal factors, (2) by changing energy intensities of selected mode and commodity combinations, and (3) by both modal factors and modification of selected mode and commodity combinations.

Modal factors – The user can change energy intensities for years 2015, 2020, 2025, 2030, 2035, 2040, 2045, and 2050 by applying factors to the preceding year's (ending in 0 or 5) energy intensities by mode. These factors, specified in the upper five rows, will be applied to all commodities using that mode. The user can activate this option by specifying, in column L, the first year in which a modal energy intensity factor will deviate from the Base Case value and the associated factor to be applied to the preceding year's value in column M. New energy intensity factors for the preceding year should be entered in columns D through K, as applicable, for subsequent 5-year increments. NEAT will linearly interpolate these factors for the intervening years. For example, the user estimates that the truck mode will reduce its energy intensity by a factor of 0.96 by 2015 relative to 2010. NEAT will assign a factor of 0.992 to 2011, 0.984 to 2012, 0.976 to 2013, and 0.968 to 2014.

Energy intensities of selected mode and commodity combinations – The user can specify the first year in which the energy intensity of a mode and commodity combination will change in the corresponding cell of column L and the associated energy intensity in column M. New energy intensities for subsequent years ending in 0 and 5 should be entered in columns D through K, as applicable. Please note that energy intensities are specified as Btu per ton-mile by using the higher heating value of fuels.[2]

Modal factors and selected mode and commodity combinations – The third option is a combination of options 1 and 2. The user can specify modal factors as explained above, and specify commodity and mode combination-specific energy intensities as described under option 2. When commodity and mode combination-specific energy intensities are specified, modal factors are ignored for those combinations and are applied to all other mode and commodity combinations.

Figure 3 shows instructions for inputting energy intensities. The top rows are for mode-specific factors, while the lower rows are for specifying commodity and mode combination-specific energy intensities.

[2] The lower heating value (also known as net calorific value) of a fuel is defined as the amount of heat released by combusting a specified quantity (initially at 25°C) and returning the temperature of the combustion products to 150°C, which assumes the latent heat of vaporization of water in the reaction products is not recovered.
The higher heating value (also known gross calorific value or gross energy) of a fuel is defined as the amount of heat released by a specified quantity (initially at 25°C) once it is combusted and the products have returned to a temperature of 25°C, which takes into account the latent heat of vaporization of water in the combustion products.

ENERGY INTENSITY (BTU/TON-MILE) BY COMMODITY AND MODE: Default energy intensity (EI) values, in BTU per ton-mile, for each mode and commodity combination are listed below. You can either accept these energy intensity values or change them. For changing these energy intensity values, you have two options: (1) Change the modal energy intensity factors at the top of this table and/or (2) Enter values for individual commodity and mode. For option (1), please type the first year in which the energy intensity change factor deviates from default in column L for the mode of interest and corresponding factor in column M. For option (2), please type the first year in which the energy intensity for a commodity and mode would change in column L and corresponding values in column M. Values (either a factor applied to modal energy intensities in the preceding year ending in 0 or 5 or commodity and mode specific Btu/ton-mile) for all subsequent years ending in zero and five should be entered in columns D through K as applicable. You can use both options in one run. In such a case commodity level value in option 2 overrides modal factor(s) and applies EI values specified for a mode within commodity and option 1 is applied to all other commodities. An EI value greater than 88,888 for a mode signifies that the mode is not applicable and should be skipped in energy calculations.

Option (1): Apply Mode Specific Change in Energy Intensities Through Multiplicative Factors	Mode	2010	2015: Factor Applied to 2010 EI	2020: Factor Applied to 2015 EI	2025: Factor Applied to 2020 EI	2030: Factor Applied to 2025 EI	2035: Factor Applied to 2030 EI	2040: Factor Applied to 2035 EI	2045: Factor Applied to 2040 EI	2050: Factor Applied to 2045 EI	1st Yr of change	1st Yr Factor
ALL COMMODITIES	Truck	1.0000	1.1250	0.9405	0.9359	0.9167	0.9269	0.9616	0.9833	0.9914		
	Rail	1.0000	1.2412	0.9633	0.9633	0.9633	0.9633	0.9633	0.9633	0.9633		
	Domestic Marine	1.0000	0.8285	0.9533	0.9533	0.9535	0.9534	0.9534	0.9547	0.9547		
	Air Freight	1.0000	1.4461	0.8744	0.8676	0.9174	0.9389	0.9412	0.9485	0.9580		
	Pipeline	1.0000	1.3601	0.8118	0.9383	0.9664	0.9828	1.0049	1.0084	1.0017		

Option (2): Commodity and Mode Specific Change in Energy Intensity in Btu/Ton-mile	Mode	2010	2015	2020	2025	2030	2035	2040	2045	2050	1st Yr of change	1st Yr EI	SCTG
Live Animals/ Fish	Truck	2,061	2,318	2,181	2,041	1,871	1,734	1,667	1,640	1,626			
	Rail	278	345	333	320	309	297	286	276	266			
	Domestic Marine	548	454	433	412	393	375	357	341	326			01
	Air Freight	13,592	19,656	17,187	14,911	13,679	12,843	12,087	11,464	10,983			
	Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999			
Cereal Grain, Other Ag Product & Animal Feed	Truck	1,686	1,896	1,784	1,669	1,530	1,418	1,364	1,341	1,330			
	Rail	229	285	274	264	254	245	236	227	219			
	Domestic Marine	452	374	357	340	324	309	295	282	269			02-04
	Air Freight	11,212	16,213	14,177	12,300	11,283	10,594	9,970	9,457	9,060			
	Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999			
Corn for Ethanol Production (From Cereal Grain)	Truck	1,676	1,885	1,773	1,660	1,521	1,410	1,356	1,333	1,322			
	Rail	239	297	286	275	265	256	246	237	228			
	Domestic Marine	473	392	374	356	340	324	309	295	281			02200
	Air Freight	11,686	16,899	14,777	12,820	11,760	11,042	10,392	9,856	9,443			
	Pipeline	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999	999,999			

FIGURE 3 Energy Intensity Input Options

3.2.4 Fuel Shares by Mode

The next set of inputs is fuel shares by mode. As explained earlier, the default fuel shares were developed by using the AEO 2017 projections.

Truck – The truck mode is assumed to consume all quantities of renewable diesel fuels in AEO 2017. The truck mode can use five fuels: petroleum diesel, biodiesel, F-T diesel, pyrolysis diesel, and LNG. The shares of these fuels are specified by volume. The user can either accept the default fuel shares or change them by specifying the first year in which such a change will take place in column L. The corresponding volumetric share is entered in column M. Volumetric shares for subsequent years ending in 0 and 5 are entered in columns D through K, as applicable. Please note that petroleum diesel shares are automatically computed as 100% minus the sum of the volumetric shares for all of the other fuels. Care should be taken to ensure that the petroleum diesel share is not less than zero.

Rail – The rail mode can use petroleum diesel, F-T diesel, pyrolysis diesel, and LNG. The fuel shares are specified by volume. The user can either accept the default fuel shares or change them by specifying the first year in which such a change will take place in column L. The corresponding volumetric share is entered in column M. Volumetric shares for subsequent years ending in 0 and 5 are entered in columns D through K, as applicable. Here, too, the shares of petroleum diesel fuel are computed automatically as 100% minus the sum of the volumetric shares for all other fuels.

Domestic marine – The domestic marine mode can use petroleum diesel, F-T diesel, pyrolysis diesel, residual fuel oil, and LNG. The user can either accept the default fuel shares or change them by specifying the first year in which such a change will take place in column L. The corresponding volumetric share is entered in column M. Volumetric shares for subsequent years ending in 0 and 5 are entered in columns D through K, as applicable. Here, volumetric fuel shares are specified for all fuels except residual fuel oil. The shares of residual fuel oil are computed as 100% minus the sum of volumetric shares of all other fuels

Aviation – The aviation mode ("air freight" NEAT) can use petroleum jet, hydro-treated renewable jet, and pyrolysis jet fuel. The user can either accept the default fuel shares or change them by specifying the first year in which such a change will take place in column L. The corresponding volumetric share is entered in column M. Volumetric shares for subsequent years ending in 0 and 5 are entered in columns D through K, as applicable. Here, the share of petroleum jet fuel is automatically computed as 100% minus the sum of volumetric shares for all other fuels.

Pipeline – Natural gas pipelines use natural gas and electricity to power their compressors. The fuel shares for natural gas pipelines are specified in terms of energy (Btu). The user can either accept the default fuel share for electricity or change it by specifying the first year in which such a change will take place in column L. The corresponding energy share is entered in column M. Energy shares for subsequent years ending in 0 and 5 are entered in columns D through K, as applicable. For natural gas pipeline, only the energy share for electricity is specified. Natural gas is assumed to provide the rest of the energy (i.e., 100% minus electricity). All other product pipelines are assumed to use electricity.

Figure 4 shows instructions for inputting fuel shares by mode and default values.

	A	B	C	D	E	F	G	H	I	J	K	L	M
417	**FUEL SHARES BY VOLUME BY FUEL TYPE WITHIN MODE:** Default shares (in terms of % of Volume, excepting for natural gas pipeline) by fuel type within mode are listed below. You can either accept these values or change them. Please type the first year in which share of a fuel type within a mode changes in column L and corresponding share values in column M. Values for all subsequent years ending in zero and five should be entered in columns D through K, as applicable.												
418	**Fuel Type**	**Mode**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**1st Yr of change**	**1st Yr Share**
419	Diesel (1)	Truck	99.2%	91.6%	87.1%	88.8%	89.9%	89.7%	89.6%	89.5%	88.8%		
420	Bio-Diesel		0.7%	6.8%	9.4%	5.6%	3.1%	3.3%	3.2%	3.2%	3.0%		
421	Renewable (F-T) Diesel		0.0%	0.0%	0.1%	0.3%	0.3%	0.4%	0.3%	0.2%	0.3%		
422	Pyrolysis Diesel		0.0%	0.1%	1.0%	2.9%	4.5%	4.7%	4.6%	4.3%	4.0%		
423	Liquefied Natural Gas (LNG) (2)		0.1%	1.5%	2.4%	2.4%	2.2%	2.0%	2.2%	2.8%	3.8%		
424	Diesel (1)	Rail	100.0%	100.0%	99.5%	94.2%	80.2%	67.7%	57.6%	49.4%	42.5%		
425	Renewable (F-T) Diesel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
426	Pyrolysis Diesel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
427	Liquefied Natural Gas (LNG) (2)		0.0%	0.0%	0.5%	5.8%	19.8%	32.3%	42.4%	50.6%	57.5%		
428	Diesel (Marine)	Domestic Marine	92.8%	96.6%	96.6%	96.7%	96.7%	96.7%	96.8%	96.8%	96.8%		
429	Renewable (F-T) Diesel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
430	Pyrolysis Diesel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
431	Liquefied Natural Gas (LNG) (2)		0.0%	0.3%	0.8%	1.3%	1.7%	2.2%	2.6%	2.6%	2.6%		
432	Residual Fuel Oil (1)		7.2%	3.1%	2.5%	2.0%	1.6%	1.1%	0.6%	0.6%	0.6%		
433	Jet Fuel (1)	Air Freight	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		
434	HR/FT Jet Fuel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
435	Pyrolysis Jet Fuel		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		
436	Natural Gas (1) (3)	Natural Gas	98.5%	98.5%	98.4%	98.4%	98.4%	98.4%	98.4%	98.4%	98.4%		
437	Electricity (3)	Pipeline	1.5%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%		
438	(1) Computed internally as 100 minus the sum of other fuels within the mode; cannot be changed by the user.												
439	(2) In gallons of LNG												
440	(3) Natural Gas and Electricity shares are specified as share of total Btu used by natural gas pipelines. All other pipelines use electricity.												

FIGURE 4 Inputting Modal Fuel Shares

3.2.5 Electricity Generation Fuel Shares

Electricity generation fuel shares are specified in percent of electricity generated by using coal, petroleum, natural gas, nuclear, and renewable sources. NEAT is populated with four scenarios: (1) AEO Reference Case, (2) Natural Gas Scenario, (3) Nuclear Scenario, and (4) Renewable Scenario. The user selects one of these scenarios and can further modify it to his/her own liking. Fuel shares for the nine projection years will show in the table, as depicted in Figure 5. The user can modify these shares by specifying the first year in which such modification begins in column L and the associated electricity generation share in column M. Shares for subsequent years ending in 0 and 5 are specified in columns D through K, as applicable. Please note that electricity generation shares for coal are computed automatically as 100% minus the sum of shares for all other fuels. Care should be taken to ensure that coal share for any year does not go below zero.

Figure 5 shows input instructions and the electricity generation share specification.

	A	B	C	D	E	F	G	H	I	J	K	L	M
442	**ELECTRICITY GENERATION FUEL SCENARIO (% kWh/Fuel):** Four scenarios for electricity generation fuel shares are available, as listed below. The default scenario represents "Reference Case" in the latest Annual Energy Outlook extended to 2050 in which coal has the largest share. The "Natural Gas Scenario" assigns increasing shares to natural gas generation, making it the dominant fuel by 2020. The "Nuclear Scenario" assigns increasing shares to nuclear generation, making it the dominant fuel by 2030. The "Renewable Scenario" assigns increasing shares to renewable sources, making them dominant by 2025. To see electricity generation fuel shares within a scenario, select a scenario. After selecting one of these scenarios, you will be allowed to make changes to your liking.												
443	**Enter the number for the scenario of interest (1, 2, 3, or 4)**		**1**			**1 = AEO Reference Case**							
444						**2 = Natural Gas Scenario**							
445						**3 = Nuclear Scenario**							
446						**4 = Renewable Scenario**							
447	**FUEL SHARES FOR THE SELECTED ELECTRICITY GENERATION SCENARIO:** The model is populated with the fuel shares (% kWh generated by fuel) for the scenario you selected. These shares are shown below. You may either accept these values or specify your own. Please type the first year in which the fuel shares will change from model's internal database for each fuel source in column L and the corresponding value in column M. New values for subsequent years ending in zero and five should be entered in columns D through K as applicable.												
448	**Electricity Generation Fuel Type**	**Mode**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**1st Yr of change**	**1st Yr Share**
449	Coal (1)	Pipeline	45.0%	33.0%	32.6%	27.8%	23.1%	21.2%	19.5%	17.9%	16.5%		
450	Petroleum		0.9%	0.7%	0.3%	0.3%	0.2%	0.2%	0.2%	0.1%	0.1%		
451	Natural Gas		24.1%	32.7%	29.3%	29.6%	33.7%	36.1%	37.5%	38.8%	40.1%		
452	Nuclear		19.7%	19.4%	18.1%	17.9%	17.3%	15.6%	14.5%	12.9%	11.3%		
453	Renewable Sources		10.4%	14.1%	19.6%	24.4%	25.7%	26.8%	28.4%	30.2%	32.0%		
454	(1) Computed internally as 100 minus the sum of other fuels; cannot be changed by the user.												

FIGURE 5 Specification of Electricity Generation Share by Primary Fuel

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4 BASE CASE RESULTS

4.1 SUMMARY TABLES

NEAT generates three summaries of Base Case and Scenario Case results: (1) modal energy results, (2) GHG results, and (3) upstream energy results. The resulting charts are presented in Section 4.2.

Modal energy – The first summary of modal energy results is provided in two parts. The upper part of this summary tabulates energy use in trillion Btu by mode and fuel type for the years 2010, 2015, 2020, 2025, 2030, 2035, 2040, 2045, and 2050. Also, a summary combining all modes and identifying fuels as petroleum fuels, biofuels, gaseous fuels, and electricity is generated. When a scenario is evaluated, the summary would show Base Case values on the left and Scenario Case values on the right. In Figure 6 we show the Base Case values only.

The lower part of the modal energy results shows modal energy consumption in physical units. The physical unit for petroleum fuels is million barrels per day of oil equivalent, for biofuels it is billion gallons, for gaseous fuels it is trillion standard cubic feet of natural gas, for electricity it is one thousand megawatt hours (MWh). Figure 7 shows energy results in physical units.

Greenhouse gas – A summary of full-fuel-cycle GHG emissions expressed as million metric tons of carbon dioxide equivalent is generated showing GHG emissions by mode and fuel type. As in the case of modal energy results, the lower part of this summary combines all modes and summarizes GHG emissions by fuel type. Figure 8 shows Base Case GHG emissions.

Upstream energy – The upstream energy consumption summary tabulates energy consumption by end-use fuel. The data are shown in trillion Btu, but do not show the type of fuel used in feedstock production and fuel production. The upper part of the summary tabulates upstream energy used for feedstock production for each mode and end-use fuel combination as shown in Figure 9.

The lower part of the upstream energy summary tabulates energy use in fuel production by end-use fuel within mode. All types of fuels used in production of the end-use fuels are summed as shown in Figure 10.

BASE CASE FREIGHT MODES ENERGY CONSUMPTION SUMMARY										
BASE CASE Name: 2017 Non-Light Duty Energy Accounting Tool Base Case With FAF 4.0 and AEO 2017 Data										
Mode	**Fuel**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
ENERGY USE SUMMARY BY FUEL TYPE WITHIN MODE (TRILLION BTU)										
Truck	Diesel	4,001.1	3,678.0	3,690.1	3,790.6	3,772.2	3,766.8	3,968.4	4,252.0	4,540.2
	Bio-Diesel	27.0	212.4	307.1	183.8	99.8	106.4	111.5	117.3	119.9
	Renewable (F-T) Diesel	0.0	0.3	1.9	10.8	11.6	12.0	12.3	7.8	12.5
	Pyrolysis Diesel	0.0	2.8	38.3	111.1	171.1	177.0	181.2	182.6	184.7
	Liquefied Natural Gas (LNG)	1.3	30.1	51.7	52.6	47.2	43.5	49.9	68.0	100.0
	TOTAL TRUCK	**4,029.5**	**3,923.6**	**4,089.1**	**4,149.0**	**4,101.9**	**4,105.8**	**4,323.2**	**4,627.7**	**4,957.4**
Rail	Diesel	488.1	553.6	563.9	558.2	516.1	479.0	455.9	429.9	401.7
	Renewable (F-T) Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Liquefied Natural Gas (LNG)	0.0	0.0	1.8	21.2	78.8	141.0	206.8	271.9	334.8
	TOTAL RAIL	**488.1**	**553.6**	**565.7**	**579.4**	**594.9**	**619.9**	**662.7**	**701.9**	**736.4**
Domestic Marine	Diesel (Marine)	215.6	166.0	160.5	166.9	167.9	171.1	180.7	186.2	190.4
	Renewable (F-T) Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Liquefied Natural Gas (LNG)	0.0	0.3	0.9	1.4	1.9	2.4	3.1	3.1	3.2
	Residual Fuel Oil	18.1	5.8	4.6	3.8	3.0	2.1	1.2	1.2	1.2
	TOTAL DOMESTIC MARINE	**233.7**	**172.1**	**166.0**	**172.1**	**172.7**	**175.6**	**184.9**	**190.6**	**194.9**
Air Freight	Jet Fuel	152.0	139.0	145.8	150.4	162.4	181.6	211.8	336.2	449.6
	HR/FT Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL AIR FREIGHT	**152.0**	**139.0**	**145.8**	**150.4**	**162.4**	**181.6**	**211.8**	**336.2**	**449.6**
Pipeline	Natural Gas	689.6	904.7	848.0	872.0	905.8	944.1	995.2	1,052.1	1,102.7
	Electricity (Natural Gas Pipeline)	79.9	83.2	78.2	80.7	84.0	87.8	92.8	98.4	103.1
	Electricity (Other Pipeline)‡	93.3	118.3	91.4	88.6	86.6	89.2	97.0	102.3	106.6
	TOTAL PIPELINE	**862.8**	**1,106.2**	**1,017.7**	**1,041.2**	**1,076.5**	**1,121.2**	**1,185.0**	**1,252.8**	**1,312.4**
ALL	**TOTAL ENERGY**	**5,766.1**	**5,894.4**	**5,984.3**	**6,092.1**	**6,108.5**	**6,204.2**	**6,567.6**	**7,109.1**	**7,650.7**
ENERGY USE SUMMARY BY FUEL TYPE (TRILLION BTU)										
ALL	Diesel	4,704.8	4,397.5	4,414.6	4,515.7	4,456.2	4,416.9	4,604.9	4,868.1	5,132.3
	Jet Fuel	152.0	139.0	145.8	150.4	162.4	181.6	211.8	336.2	449.6
	Residual Fuel Oil	18.1	5.8	4.6	3.8	3.0	2.1	1.2	1.2	1.2
	SUM OF PETROLEUM FUELS	**4,874.9**	**4,542.3**	**4,565.0**	**4,669.9**	**4,621.6**	**4,600.6**	**4,817.9**	**5,205.5**	**5,583.2**
	Bio Diesel	27.0	212.4	307.1	183.8	99.8	106.4	111.5	117.3	119.9
	Renewable (F-T) Diesel	0.0	0.3	1.9	10.8	11.6	12.0	12.3	7.8	12.5
	HR/FT Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	2.8	38.3	111.1	171.1	177.0	181.2	182.6	184.7
	Pyrolysis Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SUM OF BIOFUELS	**27.0**	**215.6**	**347.3**	**305.7**	**282.5**	**295.4**	**305.0**	**307.7**	**317.2**
	Natural Gas	689.6	904.7	848.0	872.0	905.8	944.1	995.2	1,052.1	1,102.7
	Liquefied Natural Gas (LNG)	1.3	30.4	54.4	75.3	127.9	186.9	259.7	343.1	437.9
	SUM OF GASEOUS FUELS	**690.9**	**935.1**	**902.4**	**947.3**	**1,033.7**	**1,131.1**	**1,254.9**	**1,395.2**	**1,540.6**
	ELECTRICITY	**173.2**	**201.5**	**169.6**	**169.2**	**170.7**	**177.0**	**189.8**	**200.7**	**209.7**

FIGURE 6 Base Case Modal Energy Results Summary – Trillion Btu

BASE CASE FUEL CONSUMPTION SUMMARY IN PHYSICAL UNITS										
Mode	**Fuel**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
ENERGY USE SUMMARY BY FUEL TYPE WITHIN MODE (PHYSICAL UNITS AS APPLICABLE)										
Truck	Diesel (Million Bbl/Day Oil Eqv)	1.89	1.74	1.74	1.79	1.78	1.78	1.87	2.01	2.14
	Bio-Diesel (Billion Gallons)	0.21	1.66	2.40	1.44	0.78	0.83	0.87	0.92	0.94
	Renewable Diesel (Billion Gallons)	0.00	0.00	0.01	0.08	0.09	0.09	0.09	0.06	0.10
	Pyrolysis Diesel (Billion Gallons)	0.00	0.02	0.28	0.80	1.23	1.28	1.31	1.32	1.33
	LNG (Trillion SCF NG Eqv)	0.00	0.03	0.05	0.05	0.04	0.04	0.05	0.06	0.09
Rail	Diesel (Million Bbl/Day Oil Eqv)	0.23	0.26	0.27	0.26	0.24	0.23	0.22	0.20	0.19
	Renewable Diesel (Billion Gallons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrolysis Diesel (Billion Gallons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	LNG (Trillion SCF NG Eqv)	0.00	0.00	0.00	0.02	0.07	0.13	0.19	0.25	0.31
Domestic Marine	Marine Diesel (Million Bbl/Day O E)	0.10	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09
	Renewable Diesel (Billion Gallons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrolysis Diesel (Billion Gallons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	LNG (Trillion SCF NG Eqv)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Residual Fuel Oil (Million Bbl/Day OE)	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Air Freight	Jet Fuel (Million Bbl/Day Oil Eqv)	0.07	0.07	0.07	0.07	0.08	0.09	0.10	0.16	0.21
	HR/FT Jet Fuel (Billion Gallons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrolysis Jet Fuel (Billion Gallons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pipeline	Natural Gas (Trillion SCF)	0.63	0.83	0.78	0.80	0.83	0.87	0.91	0.97	1.01
	Electricity (Thousand MWh)	50,763.8	59,049.3	49,717.2	49,601.0	50,015.0	51,889.5	55,627.5	58,827.4	61,459.2
ENERGY USE SUMMARY BY FUEL TYPE (PHYSICAL UNITS AS APPLICABLE)										
ALL	Diesel (Million Bbl/Day Oil Eqv)	2.22	2.08	2.09	2.13	2.10	2.09	2.18	2.30	2.42
	Jet Fuel (Million Bbl/Day Oil Eqv)	0.07	0.07	0.07	0.07	0.08	0.09	0.10	0.16	0.21
	Residual Fuel Oil (Million Bbl/Day OE)	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	PETROLEUM FUELS (MM B/D OE)	**2.30**	**2.15**	**2.16**	**2.21**	**2.18**	**2.17**	**2.28**	**2.46**	**2.64**
	Bio-Diesel (Billion Gallons)	0.21	1.66	2.40	1.44	0.78	0.83	0.87	0.92	0.94
	Renewable Diesel (Billion Gallons)	0.00	0.00	0.01	0.08	0.09	0.09	0.09	0.06	0.10
	Pyrolysis Diesel (Billion Gallons)	0.00	0.02	0.28	0.80	1.23	1.28	1.31	1.32	1.33
	HR/FT Jet Fuel (Billion Gallons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pyrolysis Jet Fuel (Billion Gallons)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	BIOFUELS (BILLION GALLONS)	**0.21**	**1.68**	**2.69**	**2.32**	**2.10**	**2.20**	**2.27**	**2.29**	**2.37**
	Natural Gas (Trillion SCF)	0.63	0.83	0.78	0.80	0.83	0.87	0.91	0.97	1.01
	LNG (Trillion SCF NG Eqv)	0.00	0.03	0.05	0.07	0.12	0.17	0.24	0.31	0.40
	GASEOUS FUELS (TRILLION SCF)	**0.63**	**0.86**	**0.83**	**0.87**	**0.95**	**1.04**	**1.15**	**1.28**	**1.41**
	ELECTRICITY (Thousand MWh)	50,763.8	59,049.3	49,717.2	49,601.0	50,015.0	51,889.5	55,627.5	58,827.4	61,459.2

FIGURE 7 Base Case Modal Energy Results — Physical Units

BASE CASE GREENHOUSE GAS EMISSIONS SUMMARY										
BASE CASE Name: 2017 Non-Light Duty Energy Accounting Tool Base Case With FAF 4.0 and AEO 2017 Data										
Mode	**Fuel**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
FULL FUEL CYCLE EMISSIONS BY FUEL TYPE WITHIN MODE (MILLION METRIC TONS CO_2 EQUIVALENT)										
Truck	Diesel	368.3	338.7	340.2	348.7	346.5	345.8	364.3	390.4	416.8
	Bio-Diesel	0.6	5.0	7.1	4.2	2.3	2.4	2.5	2.7	2.7
	Renewable (F-T) Diesel	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
	Pyrolysis Diesel	0.0	0.1	1.1	3.0	4.6	4.7	4.9	4.9	5.0
	Liquefied Natural Gas (LNG)	0.1	2.2	3.7	3.8	3.4	3.1	3.6	4.9	7.2
	TOTAL TRUCK	**369.0**	**346.0**	**352.1**	**359.8**	**356.9**	**356.2**	**375.4**	**402.9**	**431.8**
Rail	Diesel	45.0	51.0	52.0	51.4	47.5	44.0	41.9	39.5	36.9
	Renewable (F-T) Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Liquefied Natural Gas (LNG)	0.0	0.0	0.1	1.5	5.7	10.2	14.9	19.6	24.2
	TOTAL RAIL	**45.0**	**51.0**	**52.2**	**52.9**	**53.2**	**54.2**	**56.8**	**59.2**	**61.1**
Domestic Marine	Diesel (Marine)	20.0	15.4	14.9	15.4	15.5	15.8	16.7	17.2	17.6
	Renewable (F-T) Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Liquefied Natural Gas (LNG)	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2
	Residual Fuel Oil	1.6	0.5	0.4	0.3	0.3	0.2	0.1	0.1	0.1
	TOTAL DOMESTIC MARINE	**21.6**	**15.9**	**15.4**	**15.9**	**15.9**	**16.2**	**17.0**	**17.5**	**17.9**
Air Freight	Jet Fuel	13.3	12.2	12.8	13.2	14.2	15.9	18.5	29.4	39.3
	HR/FT Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL AIR CARGO	**13.3**	**12.2**	**12.8**	**13.2**	**14.2**	**15.9**	**18.5**	**29.4**	**39.3**
Pipeline	Natural Gas	60.1	78.9	73.9	76.0	78.9	82.3	86.7	91.7	96.1
	Electricity (Natural Gas Pipeline)	15.3	13.2	11.0	10.2	9.9	10.1	10.4	10.7	11.0
	Electricity (Other Pipeline)‡	17.9	18.7	12.8	11.2	10.2	10.3	10.9	11.2	11.4
	TOTAL PIPELINE	**93.4**	**110.8**	**97.7**	**97.4**	**99.0**	**102.7**	**108.0**	**113.6**	**118.5**
ALL	**TOTAL GHG EMISSIONS**	**542.3**	**535.9**	**530.1**	**539.2**	**539.2**	**545.2**	**575.8**	**622.6**	**668.6**
FULL FUEL CYCLE EMISSIONS BY FUEL TYPE (MILLION METRIC TONS CARBON EQUIVALENT)										
ALL	Diesel	433.2	405.2	407.1	415.5	409.5	405.7	422.9	447.1	471.3
	Jet Fuel	13.3	12.2	12.8	13.2	14.2	15.9	18.5	29.4	39.3
	Residual Fuel Oil	1.6	0.5	0.4	0.3	0.3	0.2	0.1	0.1	0.1
	SUM OF PETROLEUM FUELS	**448.1**	**417.8**	**420.3**	**429.0**	**424.0**	**421.7**	**441.5**	**476.6**	**510.7**
	Bio Diesel	0.6	5.0	7.1	4.2	2.3	2.4	2.5	2.7	2.7
	Renewable (F-T) Diesel	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
	HR/FT Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	0.1	1.1	3.0	4.6	4.7	4.9	4.9	5.0
	Pyrolysis Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SUM OF BIOFUELS	**0.6**	**5.1**	**8.2**	**7.3**	**7.0**	**7.2**	**7.5**	**7.6**	**7.8**
	Natural Gas	60.1	78.9	73.9	76.0	78.9	82.3	86.7	91.7	96.1
	Liquefied Natural Gas (LNG)	0.1	2.2	3.9	5.4	9.2	13.5	18.8	24.8	31.6
	SUM OF GASEOUS FUELS	**60.2**	**81.1**	**77.9**	**81.5**	**88.2**	**95.8**	**105.5**	**116.5**	**127.7**
	ELECTRICITY	**33.3**	**31.9**	**23.8**	**21.4**	**20.1**	**20.5**	**21.3**	**21.9**	**22.4**

FIGURE 8 Base Case GHG Emissions

BASE CASE FREIGHT MODES UPSTREAM ENERGY CONSUMPTION SUMMARY										
BASE CASE Name: 2017 Non-Light Duty Energy Accounting Tool Base Case With FAF 4.0 and AEO 2017 Data										
Mode	**End UseFuel §**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
FEEDSTOCK PRODUCTION ENERGY USE SUMMARY BY END USE FUEL TYPE WITHIN MODE (TRILLION BTU)										
Truck	Diesel	291.6	288.5	305.1	310.7	307.9	306.6	323.0	346.0	369.5
	Bio-Diesel	1.1	10.1	14.5	8.6	4.7	5.0	5.2	5.5	5.6
	Renewable (F-T) Diesel	0.0	0.0	0.1	0.4	0.4	0.4	0.4	0.3	0.4
	Pyrolysis Diesel	0.0	0.1	1.7	4.9	7.6	7.8	8.0	8.1	8.2
	Liquefied Natural Gas (LNG)	0.1	2.1	3.6	3.7	3.3	3.1	3.5	4.8	7.0
	TOTAL TRUCK	**292.8**	**300.9**	**325.0**	**328.3**	**323.9**	**322.8**	**340.1**	**364.7**	**390.8**
Rail	Diesel	35.6	43.4	46.6	45.8	42.1	39.0	37.1	35.0	32.7
	Renewable (F-T) Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Liquefied Natural Gas (LNG)	0.0	0.0	0.1	1.5	5.5	9.9	14.6	19.1	23.6
	TOTAL RAIL	**35.6**	**43.4**	**46.8**	**47.2**	**47.7**	**48.9**	**51.7**	**54.1**	**56.3**
Domestic Marine	Diesel (Marine)	15.7	13.0	13.3	13.7	13.7	13.9	14.7	15.2	15.5
	Renewable (F-T) Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Liquefied Natural Gas (LNG)	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.2
	Residual Fuel Oil	1.3	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1
	TOTAL DOMESTIC MARINE	**17.0**	**13.5**	**13.7**	**14.1**	**14.1**	**14.3**	**15.0**	**15.5**	**15.8**
Air Freight	Jet Fuel	11.2	11.0	12.1	12.4	13.4	14.9	17.4	27.6	36.9
	HR/FT Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL AIR CARGO	**11.2**	**11.0**	**12.1**	**12.4**	**13.4**	**14.9**	**17.4**	**27.6**	**36.9**
Pipeline	Natural Gas	28.5	37.2	34.8	35.7	37.1	38.7	40.8	43.1	45.2
	Electricity (Natural Gas Pipeline)	8.0	8.3	6.4	6.4	7.0	7.6	8.1	8.7	9.2
	Electricity (Other Pipeline)‡	9.4	11.8	7.5	7.0	7.2	7.7	8.5	9.0	9.5
	TOTAL PIPELINE	**45.9**	**57.3**	**48.7**	**49.1**	**51.4**	**53.9**	**57.3**	**60.8**	**63.9**
ALL	**TOTAL ENERGY**	**402.5**	**426.0**	**446.3**	**451.2**	**450.3**	**454.8**	**481.5**	**522.7**	**563.6**
FEEDSTOCK PRODUCTION ENERGY USE SUMMARY BY END USE FUEL TYPE (TRILLION BTU)										
ALL	Diesel	342.9	344.9	365.0	370.1	363.7	359.5	374.8	396.2	417.7
	Jet Fuel	11.2	11.0	12.1	12.4	13.4	14.9	17.4	27.6	36.9
	Residual Fuel Oil	1.3	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1
	SUM OF PETROLEUM FUELS	**355.4**	**356.3**	**377.5**	**382.9**	**377.3**	**374.5**	**392.2**	**423.9**	**454.7**
	Bio Diesel	1.1	10.1	14.5	8.6	4.7	5.0	5.2	5.5	5.6
	Renewable (F-T) Diesel	0.0	0.0	0.1	0.4	0.4	0.4	0.4	0.3	0.4
	HR/FT Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	0.1	1.7	4.9	7.6	7.8	8.0	8.1	8.2
	Pyrolysis Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SUM OF BIOFUELS	**1.1**	**10.3**	**16.3**	**13.9**	**12.6**	**13.2**	**13.7**	**13.8**	**14.2**
	Natural Gas	28.5	37.2	34.8	35.7	37.1	38.7	40.8	43.1	45.2
	Liquefied Natural Gas (LNG)	0.1	2.2	3.8	5.3	9.0	13.2	18.3	24.2	30.8
	SUM OF GASEOUS FUELS	**28.6**	**39.3**	**38.6**	**41.0**	**46.1**	**51.8**	**59.0**	**67.3**	**76.0**
	ELECTRICITY	**17.4**	**20.1**	**13.9**	**13.4**	**14.2**	**15.2**	**16.6**	**17.7**	**18.8**

FIGURE 9 Upstream Energy Use in Feedstock Production by Mode and End-use Fuel

BASE CASE FREIGHT MODES UPSTREAM ENERGY CONSUMPTION SUMMARY										
BASE CASE Name: 2017 Non-Light Duty Energy Accounting Tool Base Case With FAF 4.0 and AEO 2017 Data										
Mode	**End Use Fuel §**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
FUEL PRODUCTION ENERGY USE SUMMARY BY END USE FUEL TYPE WITHIN MODE (TRILLION BTU)										
Truck	Diesel	479.3	436.4	426.4	436.8	434.0	433.0	456.2	488.8	521.9
	Bio-Diesel	13.1	100.8	144.9	86.5	46.9	50.0	52.4	55.1	56.3
	Renewable (F-T) Diesel	0.0	0.3	1.9	10.8	11.6	12.0	12.2	7.8	12.5
	Pyrolysis Diesel	0.0	2.5	33.8	97.7	150.2	155.2	158.9	160.1	162.0
	Liquefied Natural Gas (LNG)	0.1	3.3	5.4	5.5	4.9	4.5	5.2	7.1	10.4
	TOTAL TRUCK	**492.5**	**543.4**	**612.3**	**637.3**	**647.6**	**654.7**	**684.8**	**718.8**	**763.1**
Rail	Diesel	58.5	65.7	65.2	64.3	59.4	55.1	52.4	49.4	46.2
	Renewable (F-T) Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Liquefied Natural Gas (LNG)	0.0	0.0	0.2	2.2	8.2	14.6	21.5	28.2	34.8
	TOTAL RAIL	**58.5**	**65.7**	**65.3**	**66.5**	**67.6**	**69.7**	**73.9**	**77.7**	**80.9**
Domestic Marine	Diesel (Marine)	25.8	19.7	18.6	19.2	19.3	19.7	20.8	21.4	21.9
	Renewable (F-T) Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Liquefied Natural Gas (LNG)	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.3
	Residual Fuel Oil	1.2	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1
	TOTAL DOMESTIC MARINE	**27.0**	**20.1**	**18.9**	**19.6**	**19.7**	**20.1**	**21.2**	**21.8**	**22.3**
Air Freight	Jet Fuel	12.0	10.8	11.1	11.4	12.3	13.8	16.1	25.5	34.1
	HR/FT Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL AIR CARGO	**12.0**	**10.8**	**11.1**	**11.4**	**12.3**	**13.8**	**16.1**	**25.5**	**34.1**
Pipeline	Natural Gas	41.6	54.3	50.6	52.0	54.0	56.2	59.2	62.6	65.6
	Electricity (Natural Gas Pipeline)	104.1	88.9	71.3	67.6	66.8	68.9	71.2	74.1	76.4
	Electricity (Other Pipeline)	121.6	126.5	83.3	74.2	68.9	70.0	74.4	77.1	79.0
	TOTAL PIPELINE	**267.3**	**269.7**	**205.1**	**193.8**	**189.6**	**195.1**	**204.9**	**213.8**	**221.1**
ALL	**TOTAL ENERGY**	**857.2**	**909.7**	**912.8**	**928.6**	**936.8**	**953.3**	**1,000.8**	**1,057.5**	**1,121.5**
FUEL PRODUCTION ENERGY USE SUMMARY BY END USE FUEL TYPE (TRILLION BTU)										
ALL	Diesel	563.5	521.8	510.1	520.3	512.7	507.7	529.4	559.6	590.0
	Jet Fuel	12.0	10.8	11.1	11.4	12.3	13.8	16.1	25.5	34.1
	Residual Fuel Oil	1.2	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1
	SUM OF PETROLEUM FUELS	**576.7**	**533.0**	**521.5**	**532.0**	**525.2**	**521.6**	**545.5**	**585.2**	**624.1**
	Bio Diesel	13.1	100.8	144.9	86.5	46.9	50.0	52.4	55.1	56.3
	Renewable (F-T) Diesel	0.0	0.3	1.9	10.8	11.6	12.0	12.2	7.8	12.5
	HR/FT Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Pyrolysis Diesel	0.0	2.5	33.8	97.7	150.2	155.2	158.9	160.1	162.0
	Pyrolysis Jet Fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	SUM OF BIOFUELS	**13.1**	**103.6**	**180.5**	**195.0**	**208.7**	**217.1**	**223.5**	**222.9**	**230.8**
	Natural Gas	41.6	54.3	50.6	52.0	54.0	56.2	59.2	62.6	65.6
	Liquefied Natural Gas (LNG)	0.1	3.4	5.7	7.8	13.3	19.4	27.0	35.6	45.5
	SUM OF GASEOUS FUELS	**41.7**	**57.6**	**56.3**	**59.8**	**67.2**	**75.6**	**86.2**	**98.3**	**111.1**
	ELECTRICITY	**225.7**	**215.4**	**154.5**	**141.8**	**135.7**	**138.9**	**145.6**	**151.1**	**155.5**

FIGURE 10 Upstream Energy Use in Fuel Production by Mode and End-use Fuel

4.2 CHARTS

The "Charts" worksheet contains four charts: (1) ton-miles by mode, (2) end-use energy consumption by mode, (3) full-fuel cycle GHG emissions by mode, and (4) upstream energy consumption by mode. The working file contains these charts for the Base Case. As soon as the user completes inputs for a scenario, these charts will represent scenario results. The original working file should be kept unchanged in order to have the Base Case charts for comparison. Note if the user changes the inputs in "Model_Inputs" then the "Charts" reflect the scenario results. Figures 11 through 14 show the Base Case charts that reflect FAF 4.0 and AEO 2017 projections.

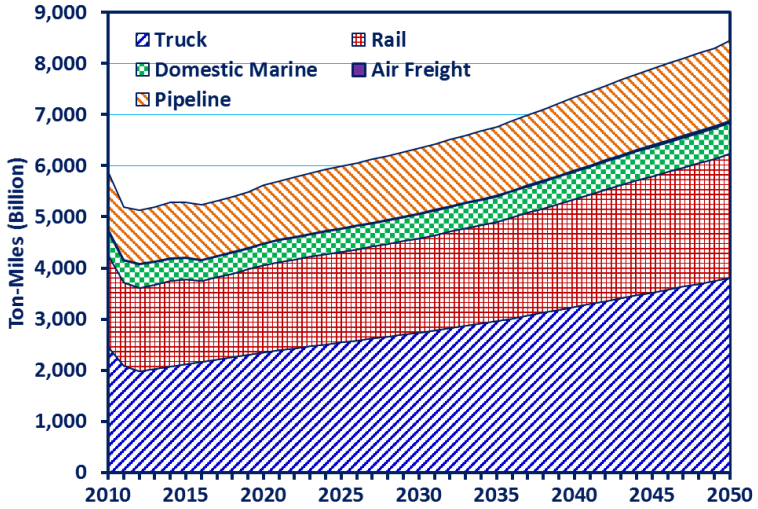

FIGURE 11 Base Case Ton-Miles by Mode

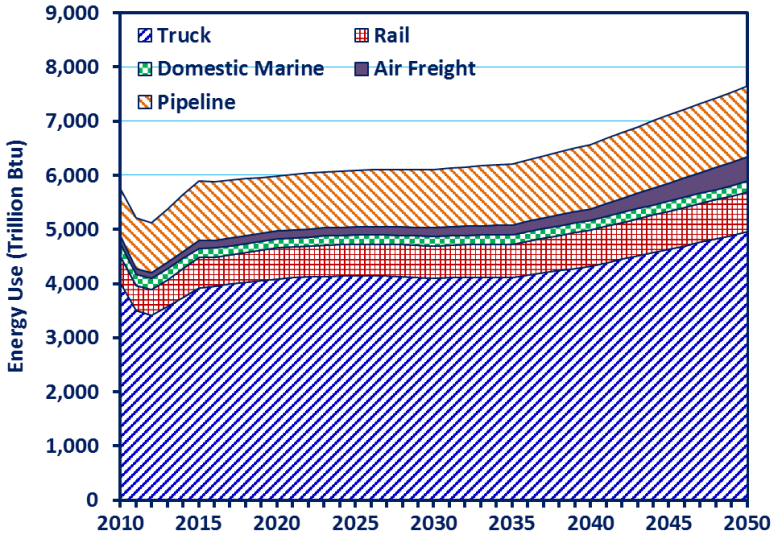

FIGURE 12 Base Case End-Use Energy Consumption by Mode

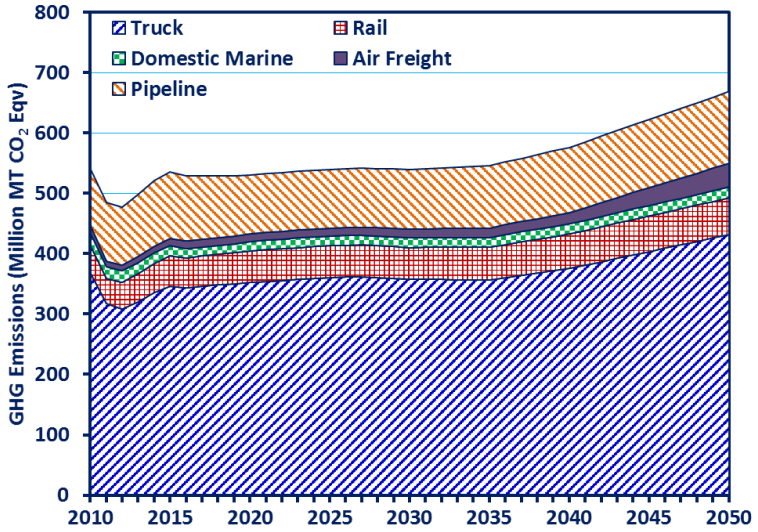

FIGURE 13 Base Case Full-Fuel-Cycle Greenhouse Gas Emissions by Mode

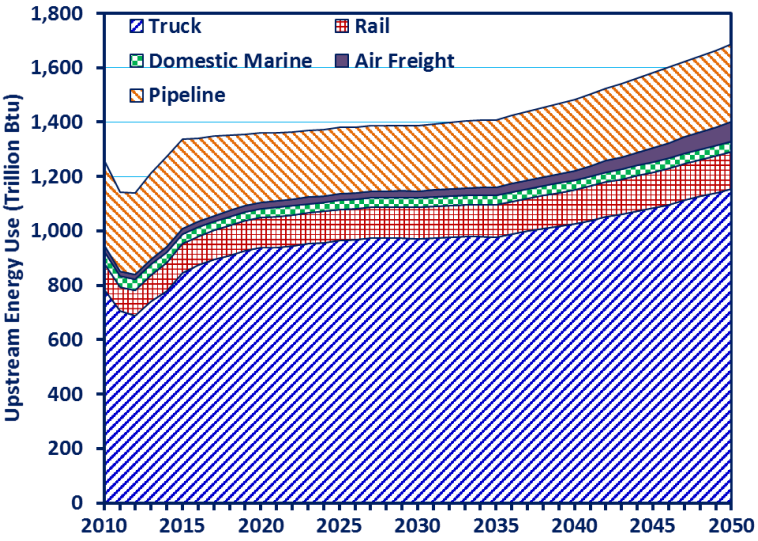

FIGURE 14 Base Case Upstream (Feedstock and Fuel Production) Energy Use by Mode

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